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Characterizing Engineering Student Social Capital in Relation to Demographics*

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The primary goal of this paper is to explore the relationships between engineering undergraduate student demographic characteristics and the social capital these students utilize when making academic and career decisions. This multi-institution study is carefully aligned with the Network Theory of Social Capital. Employing cluster analysis to characterize several key aspects of 1,410 undergraduate engineering students' social capital–namely, the composition and characterization of their social networks and indicators of their resource access–the authors explore latent patterns in the data, and uncover social capital profiles. These profiles are then related to demographic characteristics through additional statistical analyses. In particular, the paper investigates and challenges the theoretical notion regarding the significance of gender and race/ethnicity in students' social network characteristics and social capital indicators. Unlike other social capital work in education, this paper presents findings that gender and race/ethnicity are not significant or adequate for characterizing the social capital of engineering undergraduates.

Keywords: social capital; cluster analysis; underrepresented groups; name generator; resource generator

1. Introduction and background

The primary goal of this paper is to explore the relationships between engineering undergraduate student demographic characteristics and the social capital these students utilize when making academic and career decisions. Through investigating what types of social capital profiles exist among engineering students, and potential differences observed between the social capital profile groups and demographic characteristics, this study makes a step forward in characterizing the relationships between a student's demographic characteristics, the configuration of their social networks, and their social capital resource access. To better elucidate these relationships, we must first discuss what social capital is, how it has been linked to student success, and finally, how it varies among social groups.

French sociologist Pierre Bourdieu [1] and American sociologists James Coleman [2] and Nan Lin [3] are the scholars most commonly credited with introducing and analyzing the concept of social capital. In the most general sense, social capital refers to resources embedded in social networks that are available and accessed by members of that network. Portes provides a succinct description of social capital, juxtaposed with definitions of both economic and human capital [4]: "Whereas economic capital is in people's bank accounts, and human capital is inside their heads, social capital inheres in the structure of their relationships." Indeed, Coleman's 1988 seminal publication suggested that social capital is linked to the creation of human capital. That paper and others of a similar subject helped to initiate the substantial work that has since been accomplished on social capital related to education. Stanton-Salazar and Dornbush [5] defined social capital in the context of education as, "social relations from which an individual is potentially able to derive various types of institutional resources and support." Other scholars studying social capital in education have adopted a similar definition [6–9].

This work utilizes Lin's Network Theory of Social Capital [3], with aspects of Granovetter's network theory and strength of ties approach [10] that both focus on social capital at the level of the individual, specifically the makeup of an individual's network, as well as the normatively valued resources available to and accessed by an individual via social ties. When considering how social capital relates to students' academic and career decisions, we draw parallels with Lin's description of the utility of social capital in terms of achieving a goal

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[11]. An example of this is Son and Lin's work [12], which examined social contacts as an effective mechanism through which job seekers attempt to secure employment. In similar fashion, this work explores the process by which engineering students meet their academic/career goals by utilizing contacts, and thus resources, available to them through their social networks.

Generally, the education literature indicates that social capital is important for student achievement, attitudes and beliefs about their abilities, retention, and eventual occupational attainment [4, 6, 13–15]. From the perspective of social networks as a pool of resources, several types of "alters," or members of one's social network that provide resources, have been identified in this literature. These alters include family ("kin"), K-12 school personnel (e.g. teachers, counselors), college/university personnel (e.g. academic advisors, professors, program directors) and peers (e.g. classmates, mentors and tutors) [5, 6, 16–19].

Although social capital has been found to be positively associated with several educational outcomes, it is important to note that social capital is not equally accessible by all members of a group or across groups; scholars often emphasize the differential nature of social capital–that is, that social capital is "differently distributed among different social groups" [20]. Demographic characteristics such as gender, ethnicity, immigrant status, educational background and socioeconomic standing are predicted to result in differences in social capital [13, 20–23]. Specifically, social capital theory predicts that women and racial minorities are likely to have less social capital, which is generally indicated by a smaller and/or more homogeneous network and less access to resources. Thus is it essential to investigate the relationship between a student's demographic characteristics and their social capital.

For some time, differences in social capital based on demographic characteristics have been the subject of research in educational literature [24]. Many education scholars have characterized these differences in terms of social capital deficits [4, 13, 25–28]. Furthermore, a number of researchers have specifically used social capital to study minority students' aspirations [29], college choice processes (i.e. whether or not to attend college, and/or where to attend) [6, 16, 27] as well as their differential educational achievement [18, 30]. Other scholars, engaged in the study of the differences in the network composition and embedded resources based on gender, have found substantial differences between men and women [23, 31–33].

For students entering and persisting in undergraduate studies in the field of engineering, Martin, Simmons and Yu [34] assert that inequalities in social capital based on certain demographic characteristics "may be particularly acute" because engineering has been described as a privileged profession or "closed club" [35] with associated "occupational inheritance" [36]. Brown, Flick and Williamson further emphasize the particular importance of studying social capital in engineering education due in part to the "combined rigor and reported difficulty of succeeding alone in the engineering curriculum" [37]. These assertions are supported by the decades of research in both higher education and engineering education regarding student persistence. Although they have a variety of theoretical frameworks, the common thread is an emphasis is the importance of *interaction* [30, 38–52].

Considering the above-mentioned importance of social capital in education as well as its unequal distribution among and across groups, it is clear that the social capital of engineering students deserves further attention. While prior studies in education and engineering education have begun to address differences in social capital based on demographic characteristics, the relationship between students' demographic characteristics, the configuration of their social networks, and indicators of their social capital resource access has yet to be adequately characterized. Thus, it was the goal of this work to move towards understanding these interactions by characterizing the networks and resource access of undergraduate engineering students.

2. Operationalizing social capital in career/academic decisions

The prior work of the first and third authors (Martin and Miller) ([53–55]) elucidated student social capital related to academic and career decisions utilizing a "Name and Resource Generator" instrument (NRG). Developed by the authors, this NRG was then used to capture information about individual alters and those resources that students report being important to their academic and career decisions. The NRG was used by the authors to query students via the identification of important names and resources at two time points: (1) when students were deciding to pursue engineering (retrospectively) and (2) during their undergraduate engineering studies (i.e. at the time they completed the instrument). The Name Generator (NG) portion of this instrument was useful in quantifying network indicators such as size, heterogeneity, strength of ties (frequency of communication, length of relationship, and the nature of the relationship in terms of kin or non-kin), or "social network characteristics." The Resource Generator (RG) portion of the instrument allowed for the operationalization of "social capital indicators," or accessed resources embedded in an individual's network. Our operationalization of social capital follows Granovetter's [10, 56] assertion that the strength of social ties matters, and that even weak social ties to additional social circles can result in access to more beneficial social capital, by gaining access to a wider variety of non-redundant information and resources [3, 10, 12, 57, 58]. Furthermore, Lin [3] emphasizes that social capital is unequally distributed across social groups and that different types of social ties may lead to differential access to resources.

The authors' previous examination of the resources and alters used by first generation college students and their "continuing generation" peers [55] found that while overall resource access was lower for first generation college students as compared to continuing generation students, these students still accessed a relatively large "volume" of resources in making the decision to pursue engineering as a college major, and to persist once they engaged in undergraduate study. Most importantly, an analysis to identify those alters that most often provided resources revealed that first generation college students relied more on education professionals and extended family members when making their decisions to pursue a four-year engineering degree, unlike continuing generation students, who relied almost exclusively on their parents and immediate family members when making these academic and career-related decisions [55].

The current investigation is centered on probing the relationships between students' demographic characteristics, their social network characteristics and social capital indicators. Thus, rather than comparing different demographic characteristics as variables (e.g., comparing male and female students, first generation and continuing generation students, or students identifying as various races/ethnicities), a cluster analysis was undertaken to determine latent patterns in the data based on social network characteristics and social network indicators as variables [32]. In this cluster analysis, the authors found that results for the NG and RG data for the retrospective time point—when participants were making their decision to major in engineering—consisted of a three-cluster solution for the social network characteristics based on NG data. The resulting clusters possessed the following characteristics: small, kin (family)-based networks with strong ties; large networks consisting of a mixture of kin and non-kin; and small, distant networks composed of more weaker and more heterophilious ties. A two-cluster solution was found for accessed resources: the first characterized by low resource access and the second by high resource access. Lower resource access was reported most often by students who were Hispanic, first generation college, lower-income and/or had transferred from another institution, while higher resource access was reported by more students having an engineer parent or who knew an engineer before entering college [53]. Having successfully completed this work for the retrospective data, we have now used cluster analysis to characterize the social capital reported by undergraduate engineering students on the Name and Resource Generator.

2.1 Research questions

We examined the following research questions:

(a) What people and resource aspects of social capital characterize engineering undergraduate clusters?
(b) What demographic characteristics or "personal profiles" are different between these clusters?

3. Methods

Here, we used a two-step cluster analysis procedure to group student participants based on their NRG responses related to people and resource aspects of social capital (that is, social network characteristics and social capital indicators, respectively) while they were enrolled in engineering undergraduate studies. Our purpose was to develop an understanding of what types of social capital profiles exist among engineering students and if there were any demographic characteristic differences observed between the social capital groups.

3.1 Survey instrument

Our instrument draws on two sociological techniques commonly used for measuring and characterizing an individual's social capital networks and resources embedded therein: a name generator [21] and a resource generator [59]. Additionally, we also used the instrument to gather information about our participants' gender, race/ethnicity, generational status in college (operationalized as parental education attainment), family income level, parental occupation (specifically, if a parent was an engineer) and if the student knew an engineer before entering college.

Participants completed the Name Generator and Resource Generator components in one sitting by thinking about two different points in time: (1) retrospectively, when they were making the decision to major in engineering; and (2) immediately, while they were actually completing the instrument as engineering undergraduates. We used the NG portion of the instrument to amass open-ended data from participants regarding the names of specific individuals who they consider influential to their engineering academic and career-related decision making process. We then used the NG portion to collect detailed information about the participants' relationship to each alter as well demographic information about those alters.

The RG portion of our instrument listed specific resources to which participants may have access and asked participants to select, from a fixed list, each "type" of social capital alter (e.g. parent, family friend, teacher, university personnel) who provided each of the given resources, if applicable (a detailed description of the instrument can be found in [55]). The use of a resource generator instrument to capture tangible indicators of social capital is described quite clearly by Van der Gaag and Snijders: "this instrument asks about access to a fixed list of specific social resources, that each represent a vivid, concrete sub-collection of social capital [60]." The constructs we measured in the NG and RG instruments are listed in Table 1.

3.2 *Target audience and respondents*

We conducted a survey during 2010–2011 of 1,410 undergraduates engaged in undergraduate engineering study at five different US institutions; respondents ranged from first year students to those in their sixth (plus) year of engineering study. We have reported specific information about the instrument and data collection elsewhere [53–55].

3.3 *Analysis*

The overall goal of the analysis was to determine distinct groupings based on the Resource Generator *and* Name Generator responses, and the differences in the demographic characteristics of the resulting groupings. We first determined the RG and NG groupings independently of each other; this resulted in two groups each. Next, we combined the RG and NG groupings, which resulted in four groupings of students. Finally, we examined the differences between the four groups using standard correlations between the groups. The overall procedure is illustrated in Figure 1A.

3.4 *Using cluster analysis to group participants by social network characteristics and social capital indicators*

We performed two separate cluster analyses using data from the NG and RG portion independently in order to derive information about social capital network indicators and social capital characteristics. The NG analysis included network size

Table 1. Input Variables for Cluster Analyses (adapted from [53])

Cluster Analysis	Social Capital Construct	Input Variable
Name Generator (NG) Social Network Characteristics	Network Size Strength of Ties	• Number of names listed (1–8) • Average frequency of communication with contacts • % of names listed who are not kin • % of names listed who are "new" contacts • % of names listed who are "medium" contacts • % of names listed who are "stable" contacts • % of names listed who are "lifelong" contacts
	Heterophily	• % of names listed who are cross-racial • % of names listed who are cross-gender • % of names listed who are cross-age
Resource Generator (RG) Social Capital Resources	Embedded Resources	• Overall access to resources • Resource access provided by kin • Resource access provided by friends • Resource access provided by education • Resource access provided by other • Yes/No Access to specific resources: – Helps you find job or graduate school opportunities – Introduces you to people in their professional network – Helps you find an internship or job – Gives you advice about career options – Takes you to their place of engineering work – Talks to you about their own engineering work, or gives you information about engineering work – Gives you specific advice when you are faced with an academic obstacle – Writes you letters of recommendation – Recommends courses in engineering, or gives you advice about your academic options – Encourages you to stick to your engineering major – Helps you with the content in your engineering courses, helps you with an assignment, or gives you information about engineering curriculum – Provides you with financial support

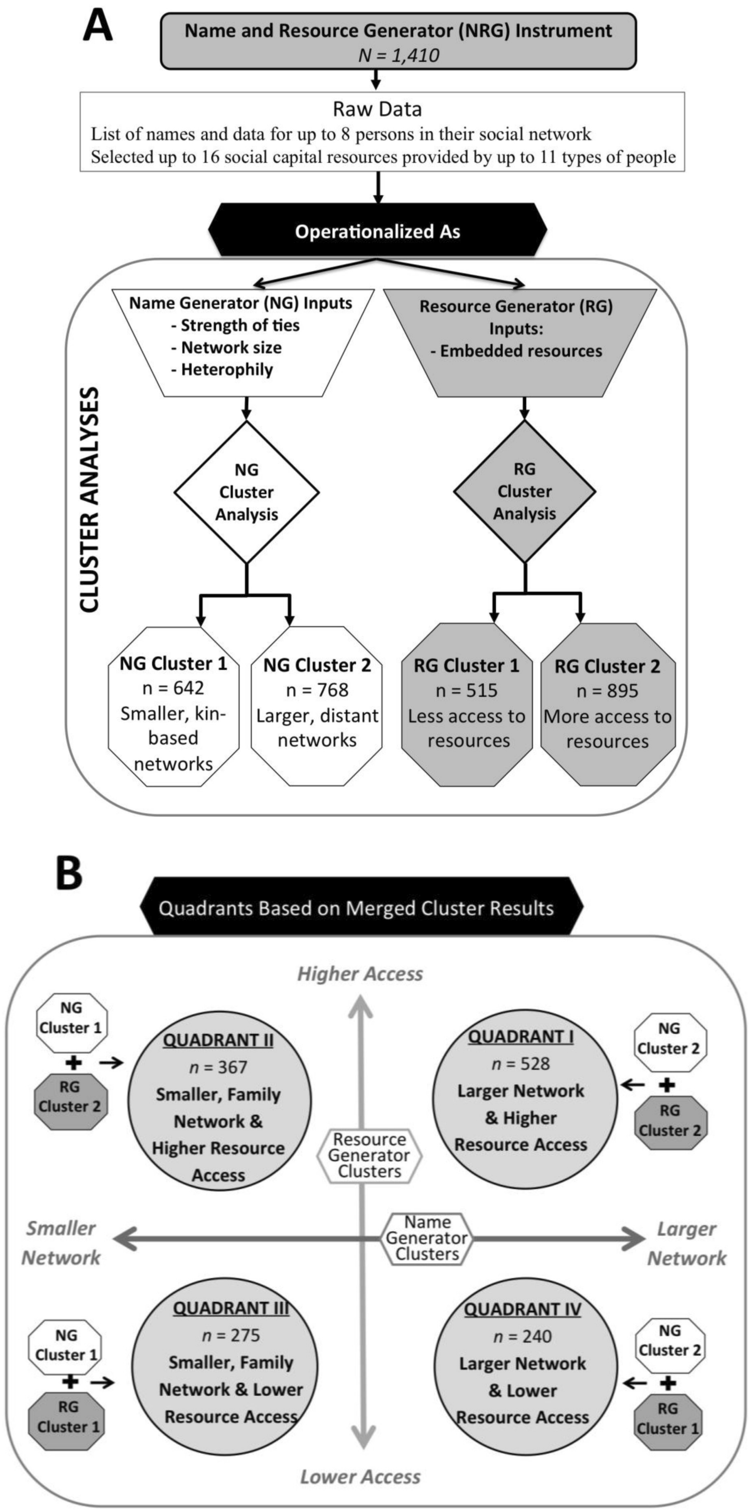

Fig. 1. (A) The general steps of the procedure starting from the collection of raw data, to the data analysis, and finally the resulting four clusters based on NG and RG data. (B) Visual summary of how the clusters were formed into quadrants.

(number of people listed), strength of ties (closeness of relationship) and heterophily (diversity of network members compared to the participant). We performed the second cluster analysis using data from the RG portion using information about the resources embedded within participants' networks. The cluster analysis using the Name Generator data yielded a two-cluster solution, as did the cluster analysis using the Resource Generator data. We then combined the cluster analysis results into what

Table 2. Cluster Analysis Results Summary

Cluster Analysis	Number of Clusters	Total NRG $N = 1{,}410$	
		Cluster 1 Size	Cluster 2 Size
Social Network Characteristics (NG inputs)	2	$n_{NG1} = 642$ (45%)	$n_{NG2} = 768$ (55%)
Social Capital Resource Access (RG inputs)	2	$n_{RG1} = 515$ (37%)	$n_{RG2} = 895$ (63%)

we term "quadrants." Figure 1B presents a visual summary of the quadrants resulting from the merging of each participant's cluster assignments from the final step of the cluster analysis. Here, the vertical axis represents variation in the number of names participants identified from the RG ("volume" of resources accessed) while the variation in the number of alters identified in the NG (size of network) is shown across the horizontal axis. The smaller octagonal shapes represent the clusters that compose each quadrant.

We undertook these separate Name Generator and Resource Generator analyses for two primary reasons. Firstly, each part of the instrument measures social capital in an entirely different manner. Secondly, as more variables are added to the cluster analysis, it becomes more difficult to create meaningful distinction between the resulting clusters—a notion that was confirmed in our pilot cluster analyses, which produced poor quality clusters with little distinction when both NG and RG variables were used in the same analysis.

3.5 Determining differences between the NG and RG groups (quadrants)

We next conducted additional statistical analyses to determine differences between the quadrants with respect to demographic characteristics of the cluster members. We used one of two specific tests, depending upon the type of data being compared. For the interval/ratio scale data (e.g., percent of cross-gender contacts), we utilized a Kruskal-Wallis H Test; for the nominal/categorical data (e.g., race/ethnicity of participant), we used a Chi-Square Test. Although both tests do identify when a variable has a significant difference, neither can discern where that difference exists. Consequently, a post hoc pairwise comparison with a Bonferroni correction was used to identify which quadrants were significantly different. A minimum p-value of less than .05 was then used to qualify significance.

4. Cluster analysis results

Both the Name Generator and Resource Generator analyses yielded two-cluster solutions. These results indicate that when considering social capital in terms of network characteristics and resource access, each describes students as having either of two general "types" of social capital qualities. These types are represented by clusters of participants, the details of which are shown in Table 2.

In Table 3, we summarize each cluster based upon the significant differences in our observations. The Name Generator cluster analysis divided students into clusters that reported either (1) smaller, kin (family)-based networks, or (2) larger networks containing more people with whom they had weaker ties. The network size for these clusters was statistically different, with the average difference in size being one person (although because the standard deviation for the larger network cluster was quite high, many students reported much larger networks). Compared to the network size, many more differences regarding strength of ties are observed, so the most important difference between

Table 3. Summary of Clusters Based on Statistical Differences

Social Network Characteristics (NG Inputs)	**Cluster 1 ($n_{NG1} = 642$)** **Smaller, Kin Network**	**Cluster 2 ($n_{NG2} = 768$)** **Larger, Distant Network**
	• Smaller network (listed 2 people on average) • Strong ties: – 95% lifelong contacts – Few non-kin – Few cross-racial (homophilious) – More frequent communication	• Larger network (listed 3 people on average) • Weaker ties: – More new contacts; few lifelong – Mostly non-kin – More cross-racial (heterophilious) – Less frequent communication
Social Capital Resource Access (RG Inputs)	**Cluster 1 ($n_{RG1} = 515$)** **Less access to engineering-related resources**	**Cluster 2 ($n_{RG2} = 895$)** **More access to engineering-related resources**
	• Lower access to resources overall • Friends provided more access to resources for this cluster	• Higher access to every resource group • More resources provided to this cluster from "other" alter types

these clusters has more to do with *who* comprises the participants' network rather than *how many* people are in the network.

In Tables 4 and 5, we detail our results from each cluster analysis described in the aforementioned summary.

Table 4. Differences in Cluster Analysis Input Variables between Clusters Formed on Social Network Characteristics (Name Generator Data)

		Overall t-test results (n = 1410)		Cluster 1 *Smaller, kin-based networks* (n = 642)		Cluster 2 *Larger, distant networks* (n = 768)	
Social Network Characteristics		**Overall p-value**	**Test Statistic**	**Mean**	**S.D.**	**Mean**	**S.D.**
Network Size	Avg. Number of Names Listed	<0.001	–11.340	2.00	1.05	**3.01*****	2.05
Strength of Ties	Avg. Freq. of Communication	<0.001	11.034	**7.32*****	1.31	6.38	1.80
	% of Names Non-Kin	<0.001	–50.737	6.4%	16.2%	**72.0%*****	29.2%
	% of Names New Contact *(known 0–2 yrs)*	<0.001	–21.146	2.3%	8.1%	**34.5%*****	37.9%
	% of Names Medium Contact *(known 3–5 yrs)*	<0.001	–17.549	2.1%	7.9%	**26.6%*****	34.5%
	% of Names Stable Contact *(known 6–15 yrs)*	<0.001	–11.104	0.9%	5.1%	**12.4%*****	25.7%
	% of Names Lifelong Contact *(known >15 yrs)*	<0.001	58.165	**94.7%*****	11.7%	26.6%	27.7%
Heterophily	% of Names Cross-Racial	<0.001	–15.162	6.8%	21.7%	**33.7%*****	40.3%
	% of Names Cross-Gender	0.174	1.359	44.5%	34.1%	42.0%	35.4%
	% of Names Cross-Age	<0.001	11.497	**92.6%*****	20.6%	75.0%	33.8%

Note: ***$p < 0.001$, **bold** indicates statistically higher cluster.

Table 5. Differences in Cluster Analysis Input Variables between Clusters Formed on Social Capital Resource Access (Resource Generator Data)

		Test Results *Aggregate: t-test* *Binary: Chi-Square*		Cluster 1 *Lower Resources* (n = 515)		Cluster 2 *Higher Resources* (n = 895)	
Engineering-related Social Capital Resources Embedded within Networks		**p-value**	**Test Statistic**	**Mean/ Count**	**S.D.**	**Mean/ Count**	**S.D.**
Aggregate Information	% of Resources Overall (binary yes/no)	<0.001	46.9	55.5%	21.1%	**92.3%*****	7.8%
	% of Resources from Friends	<0.001	–4.2	**25.9%*****	22.1%	21.7%	15.3%
	% of Resources from Other	<0.001	3.6	5.1%	11.9%	**7.6%*****	12.6%
	% of Resources from Education Personnel	<0.001	4.3	35.5%	25.6%	**41.1%*****	22.7%
	% of Resources from Kin	0.897	0.1	29.4%	24.0%	29.5%	23.5%
Access to Specific Resources	Helps you find job or graduate school opportunities	<0.001	576.9	31.1%	–	**92.1%*****	–
	Introduces you to people in their professional network	<0.001	522.5	23.9%	–	**85.0%*****	–
	Helps you find an internship or job	<0.001	440.9	44.7%	–	**94.2%*****	–
	Gives you advice about career options	<0.001	435.7	57.1%	–	**99.4%*****	–
	Takes you to their place of engineering work	<0.001	325.2	8.7%	–	**57.5%*****	–
	Information about engineering work (Talks to you about their own engineering work, or gives you information about engineering work)	<0.001	285.0	65.8%	–	**98.0%*****	–
	Gives you specific advice when you are faced with an academic obstacle	<0.001	257.6	71.3%	–	**99.1%*****	–
	Writes you letters of recommendation	<0.001	209.9	53.2%	–	**87.8%*****	–
	Long-term curricular influence (Recommends courses in engineering, or gives you advice about your academic options)	<0.001	205.8	78.1%	–	**99.8%*****	–
	Encourages you to stick to your engineering major	<0.001	154.8	78.8%	–	**98.3%*****	–
	Short-term curricular influence (Helps you with the content in your engineering courses, helps you with an assignment, or gives you information about engineering curriculum)	<0.001	149.3	84.3%	–	**100.0%*****	–
	Provides you with financial support	<0.001	81.3	72.8%	–	**90.9%*****	–

Note: ***$p < 0.001$, **bold** indicates statistically higher cluster.

4.1 Social capital "quadrants" results

We paired the cluster assignments based on both the NG and RG to create a single unique group assignment for each participant. Since both the NG and RG cluster analyses produced two clusters for a total of four possible NG+RG combinations, we refer to these unique groupings as "quadrants." We created these quadrants in order to better explore the relationship between the NG and RG cluster assignments, to further our analysis and to enhance our understanding of engineering students' social capital. Figure 2 depicts the quadrants along with the characteristics of each.

We have presented the quadrants in the fashion of a Cartesian coordinate system, where NG clusters are represented on the abscissa (smaller networks to larger networks) and the RG clusters are represented on the ordinate (lower access to higher access). This representation does not imply, however, that the NG clusters are the independent variables and RG clusters are dependent, as the axes were chosen arbitrarily. Each of the four corners where the axes intersect represents a quadrant. For example, Quadrant I in the upper right corner represents the group of participants who were assigned to both the Larger Network NG cluster and the Higher Resource Access RG cluster. That is to say, for both of the social capital measurements used (the characteristics of networks and access to resources) the individuals in a particular quadrant were higher/lower than the average. For example, individuals in Quadrant I generally have larger networks and higher resource access than their counterparts in the other three quadrants. Within each quadrant, the text in italics indicates characteristics that are unique to that quadrant based on the statistical tests for differences between the groups (see the subsequent sub-sections for a detailed discussion of these results). The boxes with arrows indicate the traits that are shared between quadrants as observed in the statistical tests.

4.2 Background and personal characteristics of quadrant members

Gender and Race/Ethnicity: Our most important finding resulted from tests yielding non-statistical significance; we did *not* observe any clear significant differences between the quadrants with respect to either gender or race/ethnicity. These findings indicate that race/ethnicity was not related to the social network characteristics and social capital indicators reported by our participants while they were enrolled in undergraduate engineering programs.

Regarding female students, while the overall p-value for gender was significant, the pairwise comparison results only revealed that fewer women were assigned to Quadrant IV compared to Quadrant III. Specifically, this finding indicates that a female

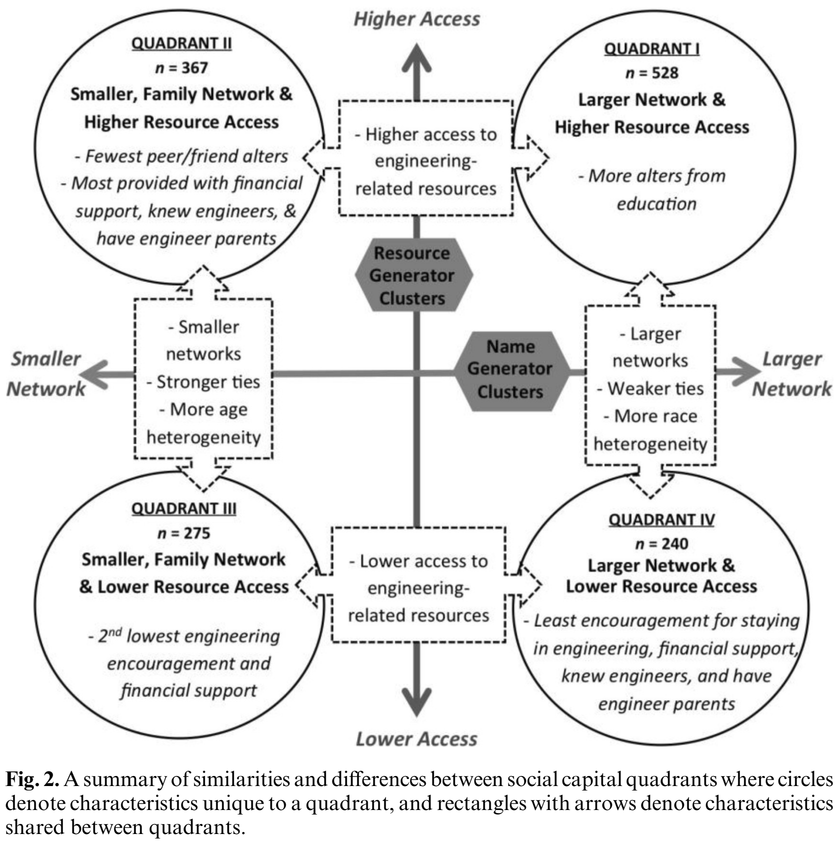

Fig. 2. A summary of similarities and differences between social capital quadrants where circles denote characteristics unique to a quadrant, and rectangles with arrows denote characteristics shared between quadrants.

Table 6. Statistical tests for differences between quadrants with respect to participant demographic characteristics

	Overall chi squared test results			**Quadrant I** *Larger Network & Higher Resources* ***n* = 528**	**Quadrant II** *Smaller Network & Higher Resources* ***n* = 367**	**Quadrant III** *Smaller Network & Lower Resources* ***n* = 275**	**Quadrant IV** *Larger Network & Lower Resources* ***n* = 240**
Social Network Characteristics	***Overall p-value***	***Test Statistic***	***Variable Categories***	***Count***	***Count***	***Count***	***Count***
Gender	0.039	8.383	Female	47.3%^{A,B}	44.7%^{A,B}	43.3%^{A}	36.3%^{B}
			Male	52.7%	55.3%	56.7%	63.8%
Race/ethnicity	0.012	10.928	American Indian or Alaskan Native	2.1%	0.3%	0.7%	0.0%
	0.329	3.436	Asian or Asian American	25.4%	20.7%	21.1%	22.1%
	0.392	3.001	Black or African American	7.4%	6.8%	4.4%	5.8%
	0.221	4.405	Hispanic or Latino/a	19.3%	18.0%	23.6%	22.9%
	0.572	2.001	Native Hawaiian or Pacific Islander	1.5%	0.8%	1.1%	2.1%
	0.637	1.702	White or Caucasian	54.0%	57.2%	57.8%	54.2%
	0.603	1.856	Other	1.7%	1.6%	2.5%	2.9%
Generational Status in College	<0.001	25.495	First Generation	26.1%^{B,C}	22.9%^{B}	32.4%^{A,C}	40.4%^{A}
			Continuing Generation	73.9%	77.1%	67.6%	59.6%
Family Income Level	<0.001	46.295	High	4.7%	6.3%	2.9%	2.1%
			Upper Medium	32.4%^{A,B}	36.2%^{A}	25.8%^{B}	22.1%^{A,B}
			Medium	34.7%	36.2%	41.5%	33.8%
			Lower Medium	16.7%^{B}	13.9%^{B}	18.2%^{A,B}	27.9%^{A}
			Low	11.6%^{A,B}	7.4%^{B}	11.6%^{A,B}	14.2%^{A}
Parent with engineering degree	<0.001	38.211	Yes	25.8%^{B}	**37.1%***^{A}	26.2%^{B}	*14.6%**^{C}
			No	74.2%	62.9%	73.8%	85.4%
Knew engineers before college	<0.001	52.946	Yes	70.8%^{B}	**80.1%***^{A}	68.4%^{B}	*52.5%**^{C}
			No	29.2%	19.9%	31.6%	47.5%

Note: **Bold** indicates significantly highest quadrant; *italics* indicates significantly lowest quadrant; superscript letters indicate group level assigned during pairwise comparisons for the purposes if identifying significant differences between groups (e.g., A, B, and C alone indicate a grouping that is significantly different from all of the others with $p < 0.05$, while A, B (or A, C) would indicate subgroups A and B (or C) are statistically similar to each other).

student with less access to social capital resources may be more likely to have a smaller network compared to her male counterpart. We observed no similar finding between the higher-resource access Quadrants I and II, nor did we note any significantly difference from Quadrant IV.

Generational Status in College: We also observed that there are more first generation college students in the two lower resource access quadrants (III and IV). Most strikingly, although the only discernible difference lies between Quadrants II and III; and although Quadrants III and IV differ not at all, many more FGC students are in Quadrant IV (larger networks and lower resource access) than in both Quadrants I and II.

Family income level: Regarding the findings on family income level, while no significant differences were observed amongst all four quadrants, the overall Chi Square tests suggested that more students in Quadrant IV came from lower-income households. This discrepancy, when compared particularly to Quadrants I and II, may be due to more first generation college students reporting lower family income levels.

Having an Engineer Parent and Knowing an Engineer: We also observed statistically significant differences in reported social capital from participants who had a parent(s) with an engineering degree and who were acquainted with engineer(s) prior to college enrollment. In both cases, Quadrant II was statistically higher than Quadrant I, and Quadrant III was statistically higher than Quadrant IV. These results indicate that participants who had an engineer parent and/or knew an engineer prior to enrolling in college reported smaller networks compared to other participants.

5. Discussion

Understanding the differences and similarities in social capital (resources and names) across populations and critical characteristics of those populations is essential for understanding and improving the equitable access to this capital. Research in this vein is unusual, which is surprising considering what we know about the importance of social capital, and the complexities and variability regarding its operationalizing and measurement. In this study, we take a first critical step to determine if social capital characteristics relevant to academic and career decisions of engineering undergraduates differ based upon demographic characteristics.

The fact that we observe no differences based upon race/ethnicity and gender supports the efficacy of cluster analysis for analyzing these data. By using cluster analysis to identify the groupings based on social capital characteristics, rather than solely using pre-defined demographic categories, we were able to capture more of the complexity of social capital. In fact, we observed no significant difference in accessed resources based on gender in both our prior work [55] and the current study. Our previous study examining the period of time during which participants were making the decision to major in engineering did reveal significant differences based on gender in composition of participants' reported social networks. Specifically, we previously determined that the size and member makeup of the networks differed for male and female students, with females reporting both small, kin-centric networks and larger networks with a mix of strong and weak ties; while male students were statistically more likely to report large, distant networks (weak ties). We also noted few differences in both network- and resource-based clusters with respect to students' racial or ethnic backgrounds. Whereas in our prior study White and Asian students reported different network makeup than Hispanic and African American students, and Hispanic students reported overall lower resource access, our current analyses of quadrants formed from clusters do not reveal differences based on race/ethnicity.

Our results are in contrast to a majority of studies in the social capital literature that indicate the significance of race/ethnicity for accessing "better" social capital–that is, social capital that leads to larger and more heterogeneous social networks and a larger volume and variety of resources that are likely to result in successful goal achievement and/or upward mobility. By comparing the results from our prior work to the results presented here, we can surmise that once in college, access to social capital appears to be more equitable. *That is, some ascribed positions appear not to be as important as attained social capital.* These changes may be due to relationships formed as a result in student involvement in campus and engineering-specific organizations and non-curricular (co-curricular) programs [61, 62]. McPherson & Smith-Lovin [31] noted that generally women's networks were not as rich in social capital because of the types of groups to which they belonged, emphasizing that different organizations contain different embedded resources. This may be one aspect where the college environment differs from society overall. In the college "society," students often participate in a broad range of activities, including those directly related to coursework as well as other campus activities [63]. These activities may offer college students access to a variety of resources, as well as multiple (and sometimes overlapping) social circles that contain potential social capital alters. Astin [63] defines involvement as "the amount of physical and psychological energy that the student devotes to the academic experience." While the Name and Resource Generator did not include items related specifically to student involvement, this is likely to be an important factor to consider when studying the social capital of engineering students.

Our results reporting a lack of difference related to gender and ethnicity have additional potential explanations. Race and gender may not adequate for characterizing the complex nature of social capital because of large within-group variations in these categories. While the network theory of social capital assumes differences based on these socially constructed categories, we know in our sample, "female students," for example, consist of a diverse group of individuals, comprised of students attending five institutions, a variety of age ranges, parental education backgrounds and occupations, both transfer and non-transfer students, and identifying with all race/ethnicity categories. Additionally, the *intersectionality* of race and gender cannot be captured when examining these variables dichotomously [64-66].

6. Limitations and future work

Our operationalization of engineering-related social capital and our retrospective approach for capturing those aspects of current engineering students' social network characteristics and social capital indicators (as described both here and in our prior research) provides many avenues for future research. One area of particular interest entails characterizing the change in students' social capital networks over time. While beyond the scope of this paper, a comparison of these findings with that from our previous work raises the question of how participants "move" from one cluster/quadrant to another during the interval of their decision to major in engineering to the point they actually enrolled in a program.

Our ability to determine the factors that influenced changes in social capital over time is limited by our retrospective (rather than longitudinal) design. We are concurrently analyzing interview data from a subset of NRG participants, which will provide another means by which to better understand the complex nature of social capital development among engineering students. Additionally, we have begun preliminary analysis of social capital and network characteristics based on students' year in college (first, second, etc.) and plan to explore this further in a future paper. We expect to characterize social capital based on year in college because our sample consisted of participants ranging from their first to sixth and greater years at their current institution.

We also would like to compare involvement in student support programs (e.g., women-in-engineering, minority-in-engineering, peer tutoring programs), non-curricular organizations (e.g., student-led professional societies). We did not collect data on participant involvement in these or other support programs, so this would be useful information for inclusion in future iterations of the NRG, as well as a suitable topic for qualitative study.

7. Conclusions

In this work, we are able to capture many of the complexities of social capital by using cluster analysis, which does not rely on demographic characteristics, but instead reveals latent patterns in the data based on social capital indicator and network characteristics. The present data show that considering engineering-related social capital in terms of mere demographic characteristics is not adequate, and findings from our prior work allude to a similar conclusion. Our observation that once students are enrolled in an undergraduate engineering program, gender and race/ethnicity are largely unrelated to their reported social network characteristics and social capital indicators is the most important conclusion of this study. We postulate that the university environment contributes to the social capital of engineering students regardless of demographic characteristics, making an individual's ascribed social capital less salient than the social capital one attains as part of the collegiate community. This work has provided a critical step towards an overarching research agenda aimed at understanding what aspects of networks and what types of resources matter for students studying engineering. Ultimately, we want to understand what "types" of social capital are useful to students in pursuing and persisting in engineering, including how specific resources and network configurations can contribute to the persistence and academic success in undergraduate engineering studies.

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