Social Network Structures of Engineering Students With Disabilities

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***Abstract*—The following full research paper explores the social networks (friends, family, faculty, etc.) of engineering students with disabilities. Engineers are tasked with designing solutions for a diverse world, and yet the engineering workforce is disproportionately made up of white, able-bodied men. As such, a persistent challenge in engineering education is not only to attract marginalized students to engineering, but to ensure their degree completion and persistence in the workforce. One predictor of persistence in engineering is the development of an engineering professional identity: a measure of interest, belonging, and competence in engineering as a subject. Those with a stronger engineering professional identity tend to have longer careers in engineering. While using engineering identity to predict success is common, the factors affecting the development of engineering identity are still being analyzed and characterized. Previous studies suggest that robust social support networks can reinforce a sense of belonging in engineering, particularly for marginalized engineering students. The following work uses pilot data to characterize effective social networks of engineering students with disabilities by responding to the following research questions: (1) What is the strength and direction of the relationship between social network homophily and disabled engineering students' sense of belonging?, and (2) What is the strength and direction of the relationship between social network capital and disabled engineering students' sense of belonging? Participants from a mid-sized, MidAtlantic university completed a validated instrument measuring engineering identity. They were then asked to provide names or initials of up to ten people they consider their closest acquaintances-friends, family, professors, advisors, coworkers, or any other relationship the student considers their "supporters". The participants additionally noted their relationship to each supporter, what form this support takes, whether or not this supporter is an engineer, whether or not this supporter has a disability, and the relationships between the supporters listed. From this information, the researchers constructed social networks for each participant and used social network analysis measures to characterize each individual's network of supporters. These measures included homophily (measure of similarity between people in the network) and social capital (measure of resources available to members of the network through their connections). Results indicate that engineering homophily (the percentage of the student's network also involved in engineering) was positively correlated to feelings of belonging, while the use of emotional support was negatively correlated to feelings of belonging.**

***Index Terms*—Disability, Social Network Analysis, Quantitative**

I. Introduction

Engineering education research increasingly prioritizes diversity, equity, and inclusion initiatives in an effort to increase the diversity of thought and expertise in the engineering workforce [1]. However, despite this coordinated effort, disability in engineering is consistently understudied and underrepresented [1]-[2]. The few studies which do exist either examine the ways non-disabled students approach designing solutions for disabled populations, or adopt a deficit-based approach to understanding the experiences of disabled engineering students, choosing to highlight their marginalization and the obstacles they face [2]. While some insights from disability studies in general education may be applicable [3], the culture of engineering programs is, in many ways, vastly different from that of other college programs [4], and thus requires targeted study. As a result, the persistence and success of disabled engineering students remains insufficiently examined.

There are many ways to explore and predict success in engineering, but one of the most common is through engineering identity [5]-[7]. Engineering identity is broadly defined as how strongly an engineering student identifies with or as an engineer, and is typically tied to interest in the field, performance in subject-area classes, and a sense of belonging in engineering [5]. Previous research has also found that engineering students who hold marginalized identities (such as non-male or non-white students) often experience an "interference" between their personal and professional identities [8]—a phenomenon which disabled engineering students may also experience. As such, examining the persistence and success of these students through an identity lens can both (a) begin to fill the gap in strengths-based research, and (b) explore an aspect of engineering success where disabled students are likely to have unique experiences.

The following work focuses primarily on the social aspect of engineering identity: the sense of belonging a student may or may not feel in the program, as well as the recognition they receive from their peers. The relationship between this factor of engineering identity and a disabled engineering student's support network is explored using social network analysis, and by responding to the following research questions: (1) What is the strength and direction of the relationship between social

network capital and disabled engineering students' sense of belonging?, and (2) What is the strength and direction of the relationship between social network homophily and disabled engineering students' sense of belonging?

II. Background

A. Identity Theory

Professional identity can be defined as "the self that has been developed with the commitment to perform competently and legitimately in the context of the profession, and its development can continue over the course of the individuals' careers" [9, p. 1505]. In other words, it is a persona that a student develops during their education which is particularly suited to their intended profession—in this case, engineering. As such, developing an engineering identity is an important part of the transition from student to graduate [10]. Previous research has also found that engineering identity is related to academic success [11], motivation towards degree completion [6], and happiness [12].

The development of any identity—including professional identity—is an inherently social process [13]. When an individual enters a new space which centers a particular identity (such as an engineering program), they begin to build a working definition of that identity through interactions with others [14]. As the individual progresses in the space, they continually adjust their definition to incorporate new information they learn [15]. In many cases, this process can be affected by personal identities the individual may already hold [16]-[17]—for example, a female student entering an engineering program may attach more meaning to her interactions with other female students as compared to male students [18]. This can lead to an engineering identity which is indivisible from the personal female identity, and therefore takes on a unique structure [8]. Additionally, a student's social network might offer them more concrete support resources—classmates can offer homework help, friends and family can provide emotional support, and instructors can act as role models, all of which contribute directly to the development of an engineering identity [19].

B. Social Network Analysis

Social network analysis (SNA) is the process by which these complex aspects of an individual's social life are operationalized. There are two major types of social networks in SNA: community networks and ego networks. Community networks explore the interconnections of an entire group, typically with the goal of understanding broad structure and dynamics (such as information flow or cliques) [20]. Ego networks, on the other hand, focus only on an individual and their immediate connections, and are therefore suited to different types of analyses [21].

One individualized social network measure is social capital. Social capital is a measure of what an individual "gets" out of their social connections—that is, how they are able to leverage the people in their network as resources [22]. Previous research has shown that engineering students tend to benefit from leveraging other engineers in their network as academic resources (i.e. helping with homework) [23]-[24], and that disabled people benefit from leveraging others in their network as social and emotional support (i.e. through friendship, distraction, or connections made through support groups) [25]-[26].

Another social network measure commonly used in examining ego networks is homophily. Homophily is a measure or similarity between the ego (that is, the survey participant) and their connections, usually expressed as a percent [27]. As discussed previously, an important part of developing an identity is interacting with others who hold the same identity—engineering students measure themselves against other engineering students and against professional engineers to create a working definition of engineering identity [14]. Additionally, marginalized engineering students often stand to benefit from being a member of an engineering community that includes other marginalized students, particularly those who share their own identity [16]-[17]. As such, both engineering homophily (the percentage of an individual's network that is also an engineer) and disability homophily (the percentage of an individual's network that is also disabled) both stand to affect the development of engineering identity.

III. Methods

A survey was distributed to all undergraduate and graduate engineering students (approximately 1500) at a mid-sized, Mid-Atlantic university. Unfortunately, because disability data is not broadly collected/available at the university, the true size of the target population is not known. The survey was hosted in Qualtrics and consisted of three major sections: demographics, engineering identity, and social network elicitation.

In the first section, the participant was asked to affirm the following statement: "I identify as disabled". If the participant did not affirm this statement, the survey ended. After this, the participant responded to standard demographic questions including their degree program and progress, age, gender, race/ethnicity, and sexual orientation. At the end of this section, the participant was asked to identify the category they felt best described their disability: physical (such as hearing loss, visual impairment, mobility impairment, etc.), chronic illness (such as diabetes, heart disease, chronic fatigue, etc.), cognitive (such as ADHD, dyslexia, etc.), or emotional (such as depression, anxiety, etc.) [28]. Participants could select multiple categories, "other", or choose not to disclose. Optionally, participants could elaborate on their selection by describing their disability in a text box.

In the second section, the participant completed Alison Godwin's engineering identity instrument [5]. The instrument consists of 13 items across three constructs: performance (how well is the student doing in their subject-area classes), enjoyment (how much does the student like participating in engineering activities), and recognition (how often the student is identified as an engineer by their peers) and is supported by strong validity evidence for the use of these items to measure

these role identity constructs [5]. This work is primarily concerned with the recognition construct, as it would theoretically be most affected by a student's social circle. The recognition construct is calculated from a set of 4 survey items, seen in Table 1.

TABLE I
SURVEY ITEMS IN THE RECOGNITION CONSTRUCT OF GODWIN'S ENGINEERING IDENTITY INSTRUMENT [5].

Prompt - For the following questions, please note how much you agree with each statement on a scale of "0 - strongly disagree" to "6 - strongly agree".
My parents see me as an engineer
My instructors see me as an engineer
My peers see me as an engineer
I have had experiences in which I was recognized as an engineer

In the third section, participants were given the following prompt:

"Who provides meaningful support to you in your pursuit of an engineering degree (up to 10)? This can include friends, classmates, advisors, other faculty, family members, etc. The order of these individuals is not important."

Participants were then asked to provide details on each supporter. First, they noted the supporter's disability status (disabled, non-disabled, or unknown) and whether or not this person had experience with engineering (as a student, instructor, or professional). This information was used to calculate homophily for each participant across a few groups: disabled supporters, engineer supporters, and disabled engineer supporters. Then, the participants would note the types of support each person in their network provided them: academic (helping with homework, studying, etc.), social (friendship, relaxation, "hanging out", etc.), or emotional (talking about stressors, being "a shoulder to cry on," etc.). Participants were able to select as many types of support as they wished for each supporter. Each of these support types is treated as social capital—a method by which the people in their network can be leveraged as a resource.

IV. RESULTS AND DISCUSSION

A total of 39 complete responses were received. Recognition was scored on a six-point scale, with 1.00 being the minimum and 6.00 being the maximum. The overall mean score for recognition was 4.66/6.00, with some students scoring as high as 6.00 and some as low as 2.50. Of these 39 participants, 24 identified as having an emotional disability, 24 as having a cognitive disability, 9 as having chronic illness, and 7 as having a physical disability. 18 participants selected multiple disabilities, with the most frequent combination being emotional and cognitive. No statistically significant differences in recognition were observed amongst these groups. As such, no subgroups were created for this study—all participants were analyzed together. A summary of descriptive statistics for the recognition construct across disability groups can be found in Table 2.

TABLE II
DESCRIPTIVE STATISTICS FOR THE RECOGNITION CONSTRUCT ACROSS FOUR DISABILITY CATEGORIES.

Measure	**Physical (n=7)**	**Chronic (n=9)**	**Cognitive (n=24)**	**Emotional (n=24)**
Mean	5.21	4.61	4.53	4.67
Median	5.25	5.00	4.50	4.88
Mode	5.00	3.75	3.75	5.00
Std. Dev.	0.68	0.86	0.85	0.84
Minimum	4.00	3.50	2.50	2.50
Maximum	6.00	5.75	6.00	6.00

A. RQ1: What is the strength and direction of the relationship between social network capital and disabled engineering students' sense of belonging?

For each student participant, the percentage of their network offering a particular type of support (academic, social, or emotional) was calculated. These percentages were plotted against the "recognition" construct of engineering identity—a numerical value on a scale of 0 to 6 which indicates the degree to which the participant's peers recognize them as an engineer. A small positive linear relationship was identified between academic support percentage and the recognition construct of the engineering identity scale, meaning that as their academic support increased, so too did their sense of belonging. Small negative linear relationships were identified between social and emotional support percentages and the recognition construct, meaning that their sense of belonging decreased as their social and emotional support increased. Of these, only the relationship between emotional support percentage and the recognition construct was found to be statistically significant. A summary of descriptive statistics for percentage of the network providing emotional support across disability groups can be found in Table 3.

TABLE III
DESCRIPTIVE STATISTICS FOR THE PERCENTAGE OF THE NETWORK PROVIDING EMOTIONAL SUPPORT ACROSS FOUR DISABILITY CATEGORIES.

Measure	**Physical (n=7)**	**Chronic (n=9)**	**Cognitive (n=24)**	**Emotional (n=24)**
Mean	0.44	0.73	0.69	0.68
Median	0.50	0.80	0.71	0.75
Mode	0.00	0.50	1.00	1.00
Std. Dev.	0.38	0.23	0.25	0.32
Minimum	0.00	0.50	0.17	0.00
Maximum	1.00	1.00	1.00	1.00

A Pearson's r correlation analysis was conducted to evaluate the strength and direction of the relationship between emotional support percentage and recognition. The normality of the continuous variables was checked and found to be within range. There was a statistically significant relationship between emotional support percentage and recognition, r = -0.32, 95% Bootstrap CI [-0.53, -0.14], p = 0.05, n = 40. The effect size for this analysis was r2 = 0.10, 95% Bootstrap CI [0.02, 0.28], indicating that 10% of the variance between emotional support percentage and recognition is shared in this data. This

is a medium effect size, and replications are likely to find a similar effect. Post hoc power analysis suggests that the test was underpowered (1β = 0.52), likely due to the small sample size. This result suggests that, as the percentage of supporters offering emotional support increases, the recognition construct decreases (Figure 1).

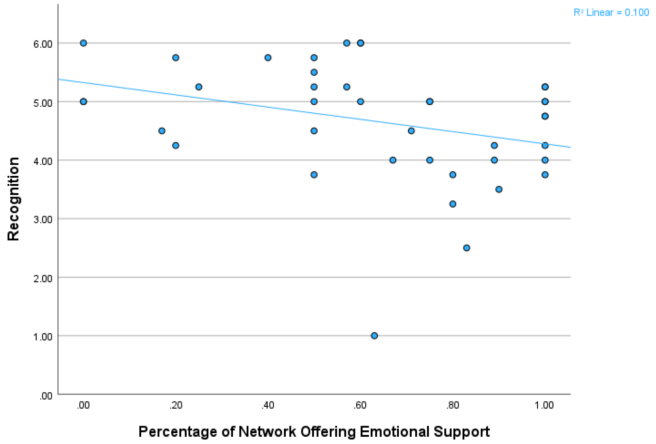

Fig. 1. Scatterplot of recognition by the percentage of a participant's network offering emotional support (n=40).

While initially a counter-intuitive result, the relationships observed may be easier to understand if causality is reversed—rather than types of support available leading to a change in identity, it may be that struggling with particular aspects of identity causes students to reach out for particular types of support. Students who have a strong sense of recognition and belonging in engineering may be afforded the time to seek academic support, while students who have a weaker sense of belonging may need to find emotional support before they can move on to improving their performance. Previous research has found that students, particularly minoritized students, tend to focus on building a sense of belonging in engineering before they move on to improving their performance [29]-[31]. As such, this result suggests that disabled engineering students struggling to build a sense of belonging in engineering may lean on emotional support from their network more heavily, though this may not always be effective in actually improving their sense of belonging.

Participants whose recognition score was below 4 (meaning they responded to a majority of recognition prompts as "slightly agree" or lower) tended to seek emotional support from engineers, both disabled and non-disabled (an average of 56.1% of these participants' emotional support came from these populations). By contrast, participants whose recognition score was above 5 (meaning they responded to a majority of recognition prompts as "agree" or "strongly agree") tended to seek emotional support from those who were neither disabled nor engineers (an average of 54.6% of these participants' emotional support came from this population). This implies that the source of support is as important as the support itself. Previous research has found that engineering students are the least likely of any college students to seek mental health support [32]-[33], likely due to the pervasive culture of stress and hardship in engineering education [12], which could lead these students to feel that the very act of seeking or needing emotional support is not "engineer-like" behavior. Therefore, seeking emotional support could lead to a decrease in their sense of belonging in engineering, particularly if they primarily seek this type of support from engineers.

B. RQ2: What is the strength and direction of the relationship between social network homophily and disabled engineering students' sense of belonging?

Homophily of each participant's support network was calculated for the following categories: engineers, disabled people, disabled engineers, non-disabled engineers, disabled non-engineers, and non-disabled non-engineers. Homophily is expressed as a percentage of the total network (i.e., if a participant's network includes ten supporters, and nine of these supporters are engineers, this participant has 90% engineering homophily). Homophily for each of these categories was plotted against the "recognition" construct of engineering identity. Overall, recognition had a positive relationship with engineering homophily (both engineers in general and non-disabled engineers), but a negative relationship with disability homophily (including disabled people in general, disabled engineers separately, and disabled non-engineers separately). Of these, only the relationship between non-disabled engineering homophily and the recognition construct was found to be statistically significant. A summary of descriptive statistics for non-disabled engineering homophily across disability groups can be found in Table 4.

TABLE IV
DESCRIPTIVE STATISTICS FOR NON-DISABLED ENGINEERING HOMOPHILY ACROSS FOUR DISABILITY CATEGORIES.

Measure	Physical (n=7)	Chronic (n=9)	Cognitive (n=24)	Emotional (n=24)
Mean	0.55	0.47	0.40	0.39
Median	0.50	0.56	0.40	0.43
Mode	0.50	0.60	0.00	0.00
Std. Dev.	0.24	0.23	0.26	0.29
Minimum	0.33	0.00	0.00	0.00
Maximum	1.00	0.70	0.83	1.00

A Pearson's r correlation analysis was conducted to evaluate the strength and direction of the relationship between non-disabled engineering homophily and recognition. The normality of the continuous variables was checked and found to be within range. There was a statistically significant relationship between non-disabled engineering homophily and recognition, r = 0.34, 95% Bootstrap CI [0.01, 0.56], p = 0.03, n = 40. The effect size for this analysis was r2 = 0.12, 95% Bootstrap CI [0.00, 0.31], indicating that 12% of the variance between non-disabled engineering homophily and recognition is shared in this data. This is a medium effect size, and replications are likely to find a similar effect. Post hoc power analysis suggests that the test was underpowered (1-β = 0.59), likely due to the

small sample size. This result suggests that, as the percentage of non-disabled engineer supporters increases, the recognition construct also increases (Figure 2).

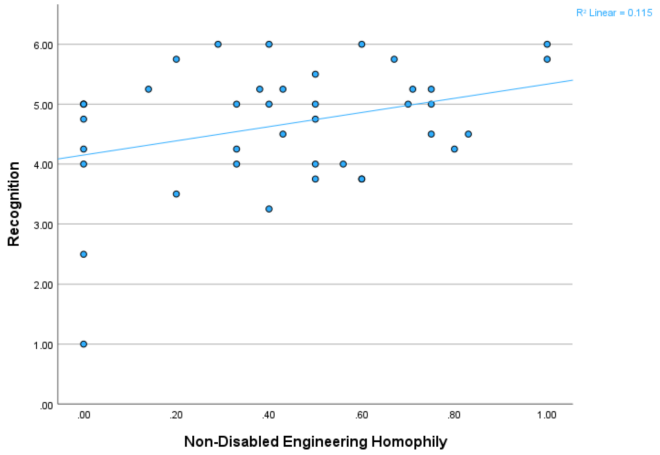

Fig. 2. Scatterplot of recognition by non-disabled engineering homophily (n=40).

A critical part of developing a professional identity (or any identity) is interacting with members of the identity "in-group"—in this case, engineers [14]. It is through these interactions that an individual creates boundaries for their identity (what is and what is not appropriate behavior for an engineer). In this process, it is possible that disabled engineering students are consciously or unconsciously placing more weight on their interactions with non-disabled engineers, particularly given the often conflicting value sets that exist between engineers and the disabled community [12]. Were this the case, it is likely that students who have a wider network of non-disabled engineering supporters could more concretely define and inhabit an engineering identity, while also standing a higher likelihood of being recognized as an engineer by this group. Research regarding disabled students in engineering is limited, but other marginalized students have reported experiencing imposter syndrome as the result of internalized sexism/racism [34]-[35]. It is also possible that the positive relationship between sense of belonging and non-disabled engineers in a student's network is a result of internalized ableism, which might be mitigated by creating a highly-compartmentalized set of identities—one "engineering" self and one "disabled" self [8]. Neurodivergent engineering students in particular have been known to disguise their neurodivergency through masking to avoid stigma [36]. While this can initially reduce deficit-based assumptions, it often leads to stress and burnout.

There may, however, be some finer nuance to this observed relationship. Participants whose recognition score was below 4 (meaning they responded to a majority of recognition prompts as "slightly agree" or lower) received all types of support from the non-disabled engineers in their network—academic (from an average of 70.0% of non-disabled engineers in their network), social (73.3%), and emotional (90%). Participants whose recognition score was above 5 (meaning they responded to a majority of recognition prompts as "agree" or "strongly agree"), on the other hand, prioritized academic support from their non-disabled engineer supporters—they received academic support from and average of 76.7% of non-disabled engineers, social support from 54.5%, and emotional support from only 32.9%. This follows from the previous observations: when students have a stronger sense of belonging, they are afforded the time and energy to seek academic support from other engineers, including non-disabled engineers [29]-[31].

V. Limitations

This paper describes the results of a preliminary exploration into a larger dataset. This paper's results are limited to a single university and, while it is difficult to estimate the number of engineering students identifying as disabled at this university, it is still likely that the number of responses (39) is a small sample of the available population. Additionally, due to the small sample size, analysis of subgroups (i.e. by disability type) was not possible. Future iterations of this work will use a larger sample, across many institutions, in pursuit of a more complete understanding of disabled engineering students' experiences.

VI. Conclusion

This study sheds light on the relationships between the social network measures and the engineering identity of disabled engineering students. These findings indicate a complicated set of relationships between a student's sense of identity, the people in their support network, and the types of support they need the most. Results suggest that disabled engineering students, particularly those struggling to establish a sense of belonging, may disproportionately seek emotional support from within their engineering networks, potentially hindering their integration into the community. Additionally, disabled engineering students with higher proportions of non-disabled engineers in their network tended to have a stronger sense of belonging. While this highlights the importance of in-group interactions in identity formation, it also raises concerns regarding potential internalized ableism and the formation of highly compartmentalized identities which may lead to burnout.

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