WIP: Influence of Laboratory Group Makeup on Recognition and Identity Development in the Engineering Graduate Student Population

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***Abstract*— The purpose of this research category work-in-progress paper is to explore the relationships between laboratory groups (specifically, the number and types of students) and the development of engineering, science, and researcher identity among engineering graduate students (EGS). We analyzed preliminary data collected as part of a national survey (current n = 826, 38% of sample target). Our sample aligns with student demographics nationally, with the majority of participants identifying as White (50%) or Asian (32%), male (63%), domestic (62%), and heterosexual (89%). A 3x3 MANOVA found a significant interaction between the type of recognition and the number of students in the lab, *F*(6,1166) = 2.29, *p* = .034, η_p^2 = .012. Univariate analyses indicated that it was scientist recognition, *F*(2,584) = 3.52, *p* = .005, η_p^2 = .018, that was significantly affected by the presence of undergraduate researchers. Specifically, participants with 2-3 and 4+ undergraduate lab mates had significantly higher scientist recognition ratings than participants with 0 or 1 undergraduate lab mates. There were no effects on engineer or researcher recognition, and no effects on scientist recognition related to graduate or postdoctoral students. These results suggest that EGS benefit from working with undergraduate students, but the relationship is complex and not always linear. Additionally, the lack of effect on engineer recognition has implications for how EGS identify and relate to fellow engineers in graduate school. Future analyses will identify trends in the overall lab composition and explore their impacts on recognition and engineering identity in more depth.**

Keywords—engineering identity, laboratory groups, engineering graduate students, recognition

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I. Introduction

This Research Category, Work-in-Progress paper explores the relationship between the composition of engineering graduate students' (EGS's) research laboratories and their perceived engineering recognition. Previous research has linked strong engineering identities to increased retention and improved performance, which are areas of particular interest among the graduate community due to the high attrition rate of graduate STEM students [1]. Studies with EGS have indicated that engineering identity at this stage differs from that described by undergraduates. For undergraduates, engineering identity is closely associated with math, science, and physics identities that develop throughout their K-12 education. For EGS, engineering identity is a burgeoning professional engineer identity that is often compared and contrasted with scientist and researcher identities [2]. Within the literature, engineering identity itself is a construct defined by engineers' perceived performance/competence, interest, and recognition [3]; of these three components, recognition from others plays a primary role in the development of engineering identity [4]. To better understand and address retention among EGS, more research into engineering recognition in graduate school is called for.

In addition to the need for further study of EGS's engineering recognition, there are also few studies exploring the unique experiences in graduate school for engineering students. For undergraduate engineers, recognition as a 'true engineer' often comes from faculty and senior engineering professionals [5], [6]. However, graduate school offers new opportunities for engineering recognition from a new population of peers, specifically fellow students with varying levels of expertise in their fields. This is in addition to research suggesting that EGS' experiences in research laboratories are key to their success in graduate school [7], [8]. Taken together, these findings lead to the following research question: What is the interaction between EGS's laboratory experiences and their engineering identities? For this study, we hypothesized that participants with more students (either undergraduate, graduate, or postdoctoral) in their research laboratories would report higher recognition scores (across the scientist, engineer, and researcher domains).

II. METHOD

A. Participants

As part of a national survey of EGS, preliminary data from 826 participants (38% of planned target) were collected, with a final sample of 587 participants analyzed (reasons for trimmed data set elaborated below). Students from approximately 200 programs and 130 institutions were invited to participate in the online survey, with a majority of students having completed at least their comprehensive exams (70%) (see Table 1 for more demographic information).

TABLE I. DEMOGRAPHICS AND OTHER CHARACTERISTICS OF FINAL SAMPLE POOL

Category	**Participant Count**	
	Levels	***Count***
Degree Milestones	Pre-Comprehensive Exams	244
	Comprehensive Exams	166
	Dissertation Proposal	119
	Dissertation Defense	23
Race/Ethnicity	American Indian/Alaska Native	0
	Asian	188
	Black/African American	9
	Hispanic/Latinx	20
	Middle Eastern/North African	17
	White	291
	Other	62
Gender Identity	Female	195
	Male	379
	Transgender/Genderqueer	6
	Other	5
Sexual Identity	Heterosexual	530
	Gay/Lesbian	11
	Bisexual	22
	Asexual	9
	Other	10

B. Measures

Factor analyses of pilot data indicated that engineering identity items loaded on three factors, the aforementioned performance/competence, interest, and recognition [9]. Only responses to the 21 items that loaded on the 'recognition' factors were included in these analyses, e.g., 'my advisor sees me as an ENGINEER', or 'my advisor sees me as a RESEARCHER', resulting in three scores (assessing engineer recognition, scientist recognition, and researcher recognition) for each participant. For the preliminary correlation, all participants who responded to the three sets of items regarding scientist, engineer, and researcher recognition were included in the analyses (n = 753).

Participants who indicated that they were members of a lab or research group with other graduate students were asked to report how many undergraduate students, graduate students, and post-doctoral students worked in their labs. Since over 99% of participants reported twenty or fewer undergraduate students in their labs, the 6 students with more than 20 undergraduate lab mates were dropped from the dataset (n = 647). Z-scores were calculated to check for and remove outliers; afterwards, the z-scores were discarded and were not used in analysis (n = 613). Raw responses were used to place students into three roughly equally-sized groups (low, medium, or high number of lab mates) for each student group (undergraduate, graduate, and post-doctoral) using the IBM SPSS V.24 Visual Binning function (see Table 2 for the codes and number of cases in each bin).

Following this, the dataset was restricted to participants who completed the three sets of recognition items and who reported working in a lab with other students. The composite variables for engineer, scientist, and researcher recognition were checked for outliers and normality. To test for outliers, z-scores were calculated and participants with scores more than three standard deviations from the mean were dropped (final n = 587). To test for normality, skewness and kurtosis of the remaining cases were calculated and compared to recommended guidelines (+/- 1.5). The identification and removal of outliers, as well as the assessment of normality, were both conducted in accordance with recommendations in the literature [10].

C. Analyses

Exploratory analyses were conducted using bivariate correlations, and three 3 x 3 MANOVAs tested the effects of other students in the lab (e.g., low, medium, or high number of undergraduate students) on the three types of recognition (scientist, engineer, and researcher). Bonferroni post-hocs were used to assess the significance and direction of differences between variable levels.

III. RESULTS

A preliminary bivariate analysis with the full dataset indicated that students who worked with others in a lab did report more scientist recognition, $r(753) = 0.26$, $p < .001$, and

TABLE II. NUMBER OF STUDENTS IN LAB, BY TYPE, CODED INTO THREE GROUPS (LOW, MEDIUM, AND HIGH)

Student Type	**Participant Count**		
	Low	***Medium***	***High***
Undergraduates			
0-1	283		
2-3		173	
4-11			131
Graduate Students			
1-4	228		
5-7		191	
8-20			168
Post-Doctoral Students			
0	301		
1		123	
2+			163

researcher recognition, $r(753) = .39$, $p < .001$, but not engineer recognition, $r(753) = -.02$, $p > .05$. To explore the relationship between the number of students in the lab and engineering recognition, 3 x 3 MANOVAs were used. Results were mixed: although there was a significant effect of number of undergraduate lab mates on engineering recognition at the multivariate level, $F(6,1166) = 2.29$, $p = .034$, $\eta_p^2 = .012$, univariate tests indicate this effect was powered by the change in scientist recognition, as there were no significant effects on engineer or researcher recognition (scientist recognition: $F(2,584) = 3.52$, $p = .005$, $\eta_p^2 = .018$; engineer recognition, $p = .291$; researcher recognition, $p = .174$).

Analysis of the group differences indicated that participants with a medium or high number of undergraduate lab mates reported significantly ($p = .021$) higher scientist recognition than their peers with a low number of undergraduate lab mates (scientist recognition means and standard errors across groups: low $M = 3.57$, $SE = .05$; medium $M = 3.78$, $SE = .06$; and high $M = 3.80$, $SE = .07$). However, scientist recognition did not differ significantly between the medium and high groups ($p = 1.00$), indicating that the gains to scientist recognition plateau even as the number of lab mates continues to increase.

The effect of number of graduate student lab mates was not significant at either the multivariate ($p = .087$) or univariate levels (scientist recognition: $p = .232$; engineer recognition: $p = .176$; and researcher recognition: $p = .095$). Similarly, non-significant results were found for the effect of the number of post-doctoral student lab mates, at both the multivariate ($p = .421$) and univariate levels (scientist recognition: $p = .195$; engineer recognition: $p = .334$; and researcher recognition: $p = .489$).

IV. DISCUSSION

Although mixed and preliminary in nature, these results offer insight into the interaction between lab group composition and engineer, scientist, and researcher identity. First, the increase in scientist recognition due to medium and high numbers of undergraduate lab mates indicates that there is a benefit for EGS who work with undergraduate students. Although the effect size would be classified as small according to the literature ($\eta_p^2 = .018$, while small effect sizes range from .01 to .05; [11], [12]) it is still a promising avenue for exploration. Future analyses can test for interaction effects across demographic groups (e.g., men and women, or well-represented and underrepresented students) as well as across degree progress and major.

Second, the fact that only scientist recognition was impacted by lab group composition is also interesting. The important role of engineering identity has been established, but the exact mechanisms and processes of engineering identity, particularly at the graduate level, are complex and largely unknown. Qualitative work with EGS has indicated that the tension between science and engineering can be both a benefit and a detriment to their identification as engineers, as well as their belonging within their field [2]. The increase in scientist recognition could thus be positive or negative; future work could use path analysis to explore the relationship between the three types of identity and graduation outcomes. Additionally, the fact that the other types of recognition (engineer and researcher) did not differ significantly by lab composition is not completely conclusive; future work with the full dataset may find interactions that are currently masked in the preliminary analysis.

A. Limitations and Future Work

The primary limitation of this work is the preliminary nature of the data and analyses. The full survey population will be nearly three times the size of the current sample, thereby increasing the amount of power available to detect small effects and interactions. Additionally, due to these limitations, the effects of each student group were analyzed independently, while in practice EGS will work in labs with varying combinations of undergraduate, graduate, and postdoctoral students simultaneously. Future work will explore the use of mixture modeling to identify profiles of laboratory groups within the population, rather than investigating the impact of each student type individually.

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