Manufacturing Inclusive Excellence: An Intersectional, Mixed Methods Study of Engineering Identity among Undergraduate Research Students at a Historically Black University

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***Abstract*—This works in progress paper is situated in a multi-year mixed methods external evaluation study of a mentored undergraduate research intervention based at a Historically Black University. This intentionally diverse setting has the potential to inform meaningful interventions to foster inclusive excellence in engineering. We leverage original external evaluation research data from surveys and individual interviews to situate what we know over multiple years of research – our own collaborative, transdisciplinary research as well as the larger research literature – to briefly synthesize and identify patterns observed to date in how student background is associated with engineering identity and career plans, from 60+ students participating in mentored materials engineering research across five cohorts. Using individual and focus group interviews to investigate intersectional experiences of students, we engage engineering students' counter-stories in context, from a critical, social justice perspective attending to multiple axes of identity. Across our analyses, we find evidence that stable and consistent support fosters and sustains engineering identity, sense of belonging, and career ambitions. Implications are offered with respect to programmatic, research, and policy directions.**

Keywords— External evaluation, Inclusivity, Student background, Higher Education, Materials science and engineering, Historically Black colleges/universities (HBCUs), Undergraduate research, Mixed Methods Research, Identity

I. INTRODUCTION

This work in progress paper is situated in a multi-year mixed methods external evaluation study of a mentored undergraduate research intervention based at a Historically Black University. This intentionally diverse setting has the potential to inform meaningful interventions to foster inclusive excellence in engineering. Researchers have found that engineering identity is important to enhance students' success during and beyond their undergraduate studies [1-3]. Yet, the opportunities to develop, sustain, and grow one's engineering identity are not uniformly distributed across students enrolled in engineering programs, nor even among those select students offered the opportunities to participate in mentored engineering research interventions [4].

Indeed, engineering students from underrepresented and structurally marginalized groups may have fewer access points to engage with engineering peers, mentors, and professionals prior to and during their collegiate studies [5-7]. These challenges can compound for students who may be underrepresented on multiple dimensions in this field, seeing their personal identities reflected less often in their intended engineering careers (e.g., gender, sexuality, race/ethnicity, socioeconomic status) [8-11]. Effective broadening participation efforts ideally "shift the default" in who engineering faculty and supervisors invite into research spaces, and offer meaningful ways to welcome students from all backgrounds to materials engineering research learning beyond the classroom [7, 12, 13].

II. MOTIVATION AND BACKGROUND

A. *Theoretical Framing*

Engineering talent is distributed across identities, but opportunities for that talent to be cultivated and developed requires intentional design, as we explain below. In turn, we approach this manuscript critically, examining engineering students' narratives in context, from a critical, social justice perspective, presenting a counterstories of their experiences in the field, with a focus on this undergraduate research training program [14]. Drawing on intersectionality theory, we investigate multiple axes of identity and lived experience, including but not limited to socioeconomic status, race, ethnicity, and gender [15-17]. We use the term *inclusive excellence* in our paper title to note the range of identities participating and engaging in this engineering research initiative, including students, mentors, and the lab environment as a whole [18].

We especially attend to engineering identity here, in this study of students training in and learning about potential careers in additive manufacturing, where the logic model described below attends to "manufacturing" engineers, and indeed students' pathways beyond these internships are conditioned not just on academic and scholarly performance, but also importantly on how they see themselves in this field. Unlike the pliable statistical code, fibers, and polymers that are the manufactured in the program's engineering labs, the student trainees have agency and are able to engage in sensemaking about their learning environments.

Engineering identity captures how students make meaning of becoming an engineer, specifically around their interest, competence, performance, and recognition [3, 19, 20]; see also research on science identity, an earlier foundational concept [21]. Research on engineering identity is often qualitative in nature [4], and mixed methods studies are rare, even more so with diverse populations such as ours [see e.g., 1]. By the nature of our focus on mentored engineering research undergraduates, this study focuses on students with demonstrated interest in engineering who have demonstrated high performance prior to entering, as selection criteria for the mentorship program. Invited participation is a recognition by program faculty and staff, reflecting these characteristics as well as the likelihood of establishing and gaining competence in engineering research through program participation. Our study therefore attends to engineering identity among a diverse student population well-positioned to further develop and enhance their engineering identity. Notably, most undergraduate student interns do not self-identify as engineers when asked in our surveys or interviews, but rather spoke instead to their intent to become one, in part through their efforts in this program [see also 22].

B. *Manufacturing Engineering Pathways: Mentored Research for Undergraduates Model*

Notably, students' primary institution of enrollment while participating in this program includes institutions across the U.S., with consistent attention to Minority Serving Institutions (especially Historically Black Colleges and Universities) and recent attention to community colleges in the Southeast, with proximity or relationships with graduate institutions with engineering doctoral programs and/or National Labs. Students who travel to the campus from other locations receive summer housing in addition to the stipends received by all students.

The training model below has been developed over a series of cohorts for nearly ten years, and associated evaluation research. We explain here its application in our study, with focused attention to undergraduates' pathways to and through completion of the summer research program. The goal of the REU Program is to encourage, empower, and prepare/train students as they matriculate into the STEM workforce through the creation of state-of-the-art student empowered research-based pathways.

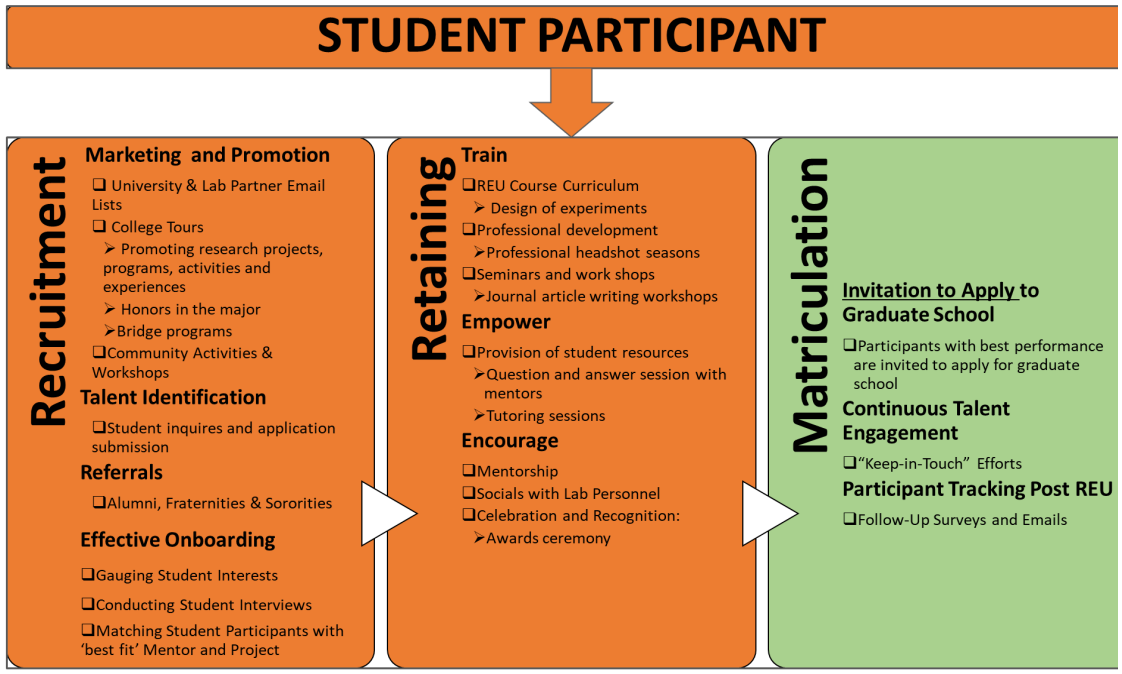

Fig. 1. Manufacturing Engineering Research Careers: 2-Dimensional Model

Figure 1 shows the outlined linear model for student empowered research-based pathways.

There are three key approaches for student empowered research-based pathways with the intent to achieve the REU program goals: 1. Recruitment, 2. Retention and 3. Matriculation. Student Participants are identified through various recruiting efforts such as advertising, marketing, referrals etc. Once identified, these students are assessed for qualification as REU participants based on various aspects of their student profiles (i.e., protentional for success in STEM, G.P.A. etc.,). The selected REU participants are then onboarded into research areas and mentor pairing to foster constant and steady support. The newly onboarded REU participants are retained in the program through training, empowerment, and encouragement activities before matriculation into STEM careers via graduate school.

III. METHODOLOGY

A. *Abbreviations and Acronyms*

REU refers to Research Experiences for Undergraduates, which are funded research programs supported by federal agencies such as the National Science Foundation, that support summer and academic year research. Latine is one of several gender-inclusive terms used at present to represent the identities of Hispanic/Latino students who sometimes alternatively use terms such as Latin*, Latinx, and Latina/o/e/x. This term is selected for ease of pronunciation in English and Spanish and its increasing use among students and scholars, alongside Latin* [see also 23].

B. *Sample and Settings*

Our analytic sample consists of multiple cohorts of undergraduate students who participated in materials science summer research internship programs between 2019 and 2023 in a diverse historically black college setting. Table 1 displays self-reported background information for the participants included in this study. The participants were diverse in terms of race, ethnicity, socioeconomic status, and home college/university, as each cohort included students from the engineering college host site as well as students recruited nationally from other campuses including research-intensive universities, other HBCUs, and most recently also community colleges. On average, at least one-third of the student participants were from the host site.

C. *Data Collection*

Our data collection efforts consisted of pre-and post-surveys administered to participants online. These were intended to gauge their knowledge and skills gained from when they first began (baseline data collection on

day 1) to their exit surveys the final days of the internship. Additionally, the evaluation research team (a) gathered students' self-ratings of their perceived competence and engineering identity, (2) a hand-written affirmation exercise on their fit within these fields [see 24, 25], and (3) facilitated audio-recorded individual interviews with participants to investigate their research internship experiences and future education and career plans. Recurring focus group meetings with engineering staff at the host university added additional triangulation of data, towards lessons learned and context for interpretation and development of implications from the findings described below.

D. *Data Analysis*

Multiple methodological approaches were employed to analyze these data. First, the survey data was analyzed using descriptive statistics to gauge changes in undergraduate participants' skills. Additionally, we transcribed and coded the focus group and interview transcriptions using an intersectional approach to identify themes and patterns that emerged from participants' counter-stories. Thematic coding of interviews attended to engineering identity, mentoring relationships, background and motivational experiences shaping students' pathways into the field prior to the internship, and their perceived competence in the field prior to and during the research internship.

E. *Trustworthiness*

To increase the trustworthiness of our study we used triangulation by including multiple sources of data afforded by our mixed methods approach. Additionally, we used a rigorous, and iterative process to analyze the qualitative data using multiple rounds of coding and theming of the data.

IV. EMERGING FINDINGS

In order to present our intersectional synthesis of findings across sources, we summarize below the multiple data types employed and findings from each set of data and corresponding analyses.

A. *Surveys: Student Demographics and Skills Gained*

Table 1 below leverages the full size of study cohorts to demonstrate the range of intersectional identities among student trainees across cohorts, to protect students' confidentiality and identity. While there are multiple identity intersections reported, we focus here on race and gender given these are the categories most studied intersectionally and most typically reported out by institutions and programs in compliance with federal reporting mandates. We attend to other potential categorizations and ways in which students make sense of their engineering and personal identity intersections elsewhere in our research.

TABLE I. STUDENT DEMOGRAPHICS ACROSS TWO MOST RECENT COHORTS

Self-Reported Identities	**(%)**		
	Gender [a]	***Men***	***Women***
Race and/or ethnicity	Asian, Asian American, &/or Pacific Islander	8.7	2.2
	Black and/or African American	41.5	46.1
	Hispanic and/or Latine	19.6	21.4
	Multiracial, Indigenous, and Other Identities	5.0	10.3
	White	25.2	20.0
Institutional Type	Community College	7.7	4.3
	Historically Black College/University	38.5	43.2
	Other Institutional Types (including HSI)	53.8	52.5

Notes. As noted above, we focus on race (in some cases described in terms of ethnicity by students) and community college enrollment given the comparably limited research base on community college engineering students, and our interest in intentionally including and incorporating their experiences. *a* While a gender binary (man or woman) was not selected by all students, it was a sufficiently small share (n<3) that we do not report this in our intersectional table here, to protect their confidentiality.

On the whole, these were not students who had consistent and early exposure to engineering knowledge and training – none of the students interviewed and surveyed self-identified as having childhood training and passion for engineering as a specific career field or discipline of study. We observed learning gains between the beginning and end of the summer on engineering competence in particular, as well as greater commitment to stay in the field and continue in research. Across the qualitative component of the evaluation, students reflected on motivation ability to push themselves "outside of their comfort zone" and – when present – family and community supports as key factors to their short-term and intended longer-term engineering success.

B. *Focus Groups*

Informal focus group discussions led and organized by the third author. These discussions in dialogue with the author team reveal the importance of making clear the hidden curriculum of engineering education. This includes structuring not only academic learning but also staff- and faculty-led guidance on how to prepare for and confidently deliver research presentations, engineering industry pitches on research-generated products, what clothes and shoes to wear for interactions with engineering faculty and visitors, and general socialization to not only engineering culture but the niche knowledge and mechanisms to present as and be received as a successful engineer. This is especially relevant to broadening participation in engineering given this knowledge – and opportunities to access such wardrobes and confident self-presentation—takes resources and practice, shared (as are often students' suits) among members of this REU community, including students and faculty researchers as well as key staff and teaching faculty who can be key points of contact and guidance for students navigating these challenging career and academic learning curves.

C. *Individual Interviews*

Findings from our analysis of individual interviews revealed undergraduate participants' experiences in the summer research internship programs further developed their engineering identity. Notably, participants described feeling more comfortable in research lab settings and confident in their ability to progress in their engineering programs. Another common theme was participants' appreciation for the opportunity to engage hands-on with research. Specifically, they routinely detailed excitement around exposure to research resources and knowledge not afforded to them before participating in the program. Overall, the internship programs seemed to foster participants' sense of belonging and enhance their interest in participation in engineering materials science research, including openness to either industry, graduate school/academia, or both pathways.

D. *Synthesis of Findings*

To date, across our analyses, we find evidence that stable and consistent support that fosters and sustains engineering identity and career ambitions. Implications are offered below with respect to programmatic, research, and policy directions for engineering education.

V. IMPLICATIONS

Findings from this ongoing evaluation study add to the current literature on engineering identity development. This paper attends throughout to the multiplicity of identities held by undergraduate students pursuing engineering research and careers. Future research will continue to explore engineering identity development, mentorship, and internship opportunities. With respect to recommended policy and practice changes that engineering educators, administrators, and other stakeholders should consider enhancing structured supports to support students inclusive of all backgrounds achieve excellence in engineering.

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