Gatekeepers to Broadening Participation in Engineering

Investigating variation across high schools comparing who could go versus who does go into engineering

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***Abstract*—This paper introduces the Gatekeepers Study, a three-year project with the goal of examining variation in enrollment in postsecondary engineering programs for students from Virginia high schools. Our research takes a macroscopic, systemic view of an entire state's high school-to-postsecondary engineering pathway to understand how each high school performs in terms of having its students from underrepresented groups who fit an engineering academic profile actually choose to enroll in an engineering postsecondary program. We frame our research holistically to understand how the variety of potential gatekeepers—including the people, places, programs, and policies— might be positioned, tweaked, or trained to support a more diverse population of students who choose to enroll in postsecondary engineering programs. This mixed-methods research design is organized into three sequential phases and will be grounded theoretically using Social Cognitive Career Theory to guide variable identification and qualitative protocol development. We are currently in Phase 1 and will describe preliminary results.**

Keywords—broadening participation; data analytics; engineering pathway

I. INTRODUCTION

Despite continued investments in recruitment and outreach initiatives, undergraduate engineering still lacks representation from segments of the population, some of which are among the fastest growing demographics in the United States. Although 58% of all bachelor's degrees and approximately half of all STEM degrees awarded since 2000 have been to female students [1], only 17.5% of engineering bachelor's degrees in 2011–2012 were earned by women [2]. Similarly, the lack of racial/ethnic diversity within undergraduate engineering is of particular concern. From 2002 to 2012, the percentage of African Americans enrolled in engineering programs actually declined from 5.3% to 4.2%, and the percentage of Hispanic Americans only rose from 7.3% to 9.3% [3]. Likewise, a disparity remains with students from lower socioeconomic statuses (SES); despite an increase in college aspirations of low SES students, fewer students actually begin college immediately following high school than self-reported intentions during high school would predict [4], [5].

Determining the causes of this persistent underrepresentation remains a continued challenge for researchers. Recent inquiries indicate that gender disparities in representation within engineering may be related to differences in self-efficacy [6], interest [7], levels of exposure to engineering before college [8], or viable major or career options [9]. Substantial research has uncovered that Black [10] and Hispanic (e.g. [11], [12]) students in aggregate suffer from a lack of preparation in basic mathematics and science and face stereotype threat in engineering programs. Much of the previous literature has focused on such specific variables that differentiate these students from majority populations in engineering. Our approach is different; instead of using subpopulations as the starting point, we start at the high school level and consider how such variables vary systematically across an entire state.

Given the amount of research focused on the K-16 pathway, it is surprising how little research has focused on location-based disparities, in particular on how students' high school contexts influence academic major choice [13]. Where an individual lives greatly impacts future employment opportunities, education attainment, and social interaction [14], [15]. Additionally, research on lower SES students from Appalachia also shows that the people with whom students interact regarding potential engineering career choices are also critically important [16]. Thinking at a school level of analysis holistically combines student background and educational experience variables that may influence students' enrollment in an engineering program. High schools, in particular teacher expectations, peer environment, access to well-informed guidance counselors, and other school resources and opportunities, play an important role in determining how students will position themselves for college [17]. Simultaneously, parental influence and the surrounding community largely dictate a student's social and cultural capital and subsequent major choice [18], [19]. Because the spatial variation of resource distribution and human capital is not random [20] and because school and community contexts directly influence high school outcomes [21], this project considers variation across those contexts to be paramount in the K–16 engineering pathway discussion [22]. For this reason, we address the overarching research question: Where and why are there demographic variations across high schools in the proportion of students who fit an engineering academic profile but do not enroll in an engineering major?

II. THEORETICAL FRAMEWORKS

Many personal and contextual factors contribute to eventual career choices. Social cognitive career theory (SCCT) [23] is a framework that encapsulates a wide variety of factors—we use SCCT to ground our study and organize data collection..

Originally developed by Lent, Brown, and Hackett [23] and modified by Lent and Brown [24], SCCT describes the relationship between person, environment, and behavior on career interest formation, choice, and performance. The model seeks to understand the process (and resulting pathway) during which students form academic and career choice goals and determine supporting actions to attain their goals [23]. Researchers do not advocate for using universal application, suggesting instead the use of subject matter specificity of measures to improve data fit within SCCT [25], [26], such as with the focus on engineering within the current study. The framework has been used in both academic [27] and industry contexts [28], [29] to investigate how engineering students and professionals develop beliefs about engineering careers and how beliefs about outcomes contribute to career interests, goals, and actions. Our study will make an important contribution to this literature by focusing on a specific section of the pathway to an engineering career and explore variation across subpopulations and local contexts.

Person Inputs (such as the demographic variables under investigation in our study) and Distal Contextual Influences (such as a student's community) form the basis of Learning Experiences which lead to both Self-Efficacy and Outcome Expectations. Self-efficacy and outcome expectations, along with Proximal Environmental Influences (i.e., supports and barriers, or the gatekeepers, which is of particular interest in this study), influence a student's Interests, Career Goals, and resulting Actions. Performance Attainment of those actions enacts a feedback loop to influence Learning Experiences and the remainder of the cycle. The literature further supports our focus on understanding variation in school-level differences because pathways for underrepresented students can be more influenced by environmental contextual influences and outcome expectations than other elements in the model [4].

In summary, SCCT provides a framework and a body of literature to organize the complex interactions between students' goals, interests, and self-efficacies, which are informed by a variety of contextual influences and learning experiences. We will use the framework and prior literature to inform variable selection in our quantitative phase and develop comprehensive interview protocols and surveys during latter phases to ensure that we gather data that encompass all elements of this complex process.

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III. STUDY DESIGN

Our mixed methods design is organized into three phases and will answer the overarching research question: Where and why are there demographic variations across high schools in the proportion of students who fit an engineering academic profile but do not enroll in an engineering major? The first quantitative phase leverages the Virginia Longitudinal Data System (VLDS), which compiles student-level data from all Virginia K–12 students (e.g. student demographics, high school attended, standardized testing, course enrollment, AP test scores, postsecondary program of enrollment). VLDS enables automated data de-identification and linkage at the individual-level over time. Although we will be using individual student data, our main analyses will focus on differences across high schools. VLDS is capable of quantifying the association between high school course enrollment and postsecondary institution enrollment in a way that could be shared with students, parents, and guidance counselors throughout the college planning process [30]. The quantitative phase will inform the selection of eight case study sites that exhibit high variation from one another. In Phases 2 and 3, we will determine whether the gatekeepers at schools with higher engineering yields out of their population of students who appear academically able to choose engineering operate differently from gatekeepers at other schools. Phase 2 will be an in-depth qualitative study of gatekeepers at those eight schools. Although we will collect data from people, "gatekeepers" also encompasses policies, programs, and places, so we will ask about these specifically. Phase 2 findings will inform two Phase 3 surveys: 1) a student survey at the eight schools to determine the alignment between what our interviewees say are influences versus what students say drive them toward or away from engineering, and 2) a survey of teachers, guidance counselors, and administrators at the eight schools.

A. *Quantitative (Phase 1)*

Phase 1 is guided by the research question: How do the academic profiles of Virginia high school students who enroll in postsecondary engineering programs vary across and within Virginia high schools?

Our data analysis begins in step 1 at the individual high school level. For each of the 310 high schools in the data set, we apply a filter to divide the data between those who enrolled in a postsecondary engineering program and those who did not. Using VLDS demographic variables from those students enrolling in engineering as inputs for cluster analysis (e.g. gender, disadvantaged status, race/ethnicity), we develop school-level profiles for qualitive case selection. In step 2, using all VLDS academic variables from those students enrolling in engineering as inputs for cluster analysis, we will develop academic profiles of engineering students. Using discriminant function analysis (or logistic regression depending on high school sample size), we will compare each student who did not enroll in an engineering program to those engineering student academic profiles to see if any strongly fit into one of those profiles. These are "possible-fit" students because they seem to fit an engineering student profile at their school but ultimately did not choose to enroll in engineering. Having developed profiles and possible-fit populations at each high school, we will continue the investigation to identify possible systemic issues.

B. *Qualitative (Phase 2)*

Phase 2 is guided by the research question: What local and contextual factors contribute to the variation in ratios between high schools and across demographic characteristics?

Through the quantitative phase of the project, we will have identified 1) engineering academic profiles for students from Virginia high schools, 2) proportions of students at each high school that fit these profiles but do not enroll in engineering programs in college (i.e., "possible-fits"), 3) variation in proportions within each high school by demographic variables, and 4) variation in proportions by school-level variables. Using the results from the school-level analysis, we will purposefully choose 8 case sites that appear different from one another while balancing the need for sufficient but not overwhelming diversity among cases [31], [32]. We recognize that we will not be able to control for every meaningful variable in our qualitative case study analysis. Therefore, we will select our cases to enable us to control key variables sufficiently to yield meaningful findings.

At each case study site, we will interview 10-15 "gatekeepers" including principals, guidance counselors, career coaches, and select teachers. Some interview participants, such as guidance counselors and career coaches, will be identified in advance, and we will then use a snowball sampling approach [33] to identify other relevant participants at each site. We will design interview protocols based on the findings from the quantitative analyses as well as from relevant literature. For example, literature on low SES populations in rural areas suggests that valued people (e.g., teachers) are key in helping students see engineering careers as a possibility [34], [35]. Therefore, we would ask guidance counselors about how students learn about engineering within the school system and from whom, and we would seek to interview those identified people.

All interviews will be recorded and transcribed verbatim. Transcripts will be segmented, with one or more coding categories assigned to capture the important aspects of each segment using both a priori codes grounded in appropriate literature about academic and career pathways, underrepresented students in engineering, and impacts of institutional policies and practices using SCCT constructs and emergent findings [33]. Following multi-case methods, interviews will be analyzed on a case-by-case basis before looking across cases for similarities and differences [36], [37]. To ensure the quality of the analysis, strategies such as member-checking [38], verifying interview interpretations with participants, and researcher triangulation [39] will be incorporated.

In summary, this phase will yield data about gatekeepers within and across schools that will explain differences across high schools regarding student intentions to pursue engineering. Our analysis will also yield key characteristics (demographic and/or school-level variables) not currently revealed by VLDS that could be considered for possible inclusion in future state longitudinal data systems and for dissemination.

C. *Quantitative (Phase 3)*

Phase 3 is guided by the research question: How do students and gatekeepers align in their perceptions of influences on students' interest in enrolling in an engineering postsecondary program?

Phase 2 findings will inform the development and deployment of two surveys for Phase 3: one for students, and one for people serving as gatekeepers at the eight case study schools. The first survey will be administered to high school students across all four years with the intention of determining the alignment between what interview participants (i.e., gatekeepers) said were influences versus what students say drive them toward or away from engineering. The second survey will be administered to a broader sampling of principals, guidance counselors, career coaches and teachers at the eight schools with the purpose of confirming interview findings with a larger sample. A secondary purpose of each survey is to create self-assessment tools for school systems to use to evaluate themselves going forward. For example, outcomes of this study will include key characteristics and indicators to inform potential resource allocation or policy changes, and the surveys would provide evaluative tools.

Student Survey—This survey will directly ask about the factors identified through the interviews (e.g., choices about enrolling in AP courses or not) but will also ask about factors that may be relevant from students' perspectives that were not highlighted by gatekeepers. For example, whereas guidance counselors and other school personnel may act as gatekeepers within schools, informal engineering opportunities may be more widely emphasized by students and attractive or available to students who initially may not be seen as "engineering material" by academic counselors. Informal engineering activities may thus represent a potent alternate route into an eventual engineering track, and so our survey will seek information about those opportunities, which include: 1) school-related opportunities for extracurricular participation in STEM-related activities (e.g., Robotics, Math Counts, and other competitive STEM team events), and 2) extra-school opportunities such as jobs, Lego League, Boys Scouts, and 4-H Club. Evaluation research on the latter program–which heavily promoted STEM in the 1990s–showed high student STEM-interest and ambition, particularly compared to a national sample of high school seniors (77% wanted to pursue a STEM career vs 37% nationally) [40]. Although not focused exclusively on engineering, these STEM-promoting clubs may be particularly critical for rural youth in promoting persistence in STEM, engineering interest, and high school course taking (e.g. [41]).

Since course enrollment choices leading to or away from engineering can happen at any time in high school, we will administer the survey to students across all four years at each of eight case site high schools. The survey will be on-line via Virginia Tech Qualtrics, and informed student assent and legal guardian consent would precede entry into the survey. We will analyze the surveys to determine which factors students cite as important for choices toward or away from engineering careers and compare this list to the list produced by gatekeepers at the same site and across sites.

Gatekeeper Survey—All teachers and administrators at each of the case study schools will be invited to complete a survey designed for gatekeepers that will be administered on-line via Virginia Tech Qualtrics. The survey will ask questions about the factors identified in the interviews. We recognize that interviews are a time- and cost-intensive means of collecting and analyzing data, and so developing informational survey questions would enable us to gather relevant information on a broader scale. We will analyze surveys to determine what factors gatekeepers cite as important for choices towards or away from engineering careers and will compare this list to the list generated by students at the same site and across sites.

IV. CURRENT STATUS

Quantitative Phase 1 is already underway. We have begun data analysis to develop school-level profiles beginning by linking individuals and schools across data sets. We expect qualitative case selection to be complete in the upcoming months and for gatekeeper interviews to commence towards the end of 2017.

V. PRELIMINARY FINDINGS

Preliminary findings are based on data manipulations in VLDS data sets. We have begun to explore the National Student Clearinghouse (NSC), State Council of Higher Education for Virginia (SCHEV), and Student Records collections. NCS and SCHEV data have been merged to fill gaps in the postsecondary enrollment data. From the Virginia Department of Education Student Records, we found that there are over one million unique individuals for which we have high school variables. It is important to note that we will not need to make inferences from samples to a broader population because we have access to population data for the entire state of Virginia. Figure 1 illustrates the preliminary linking of variables of interest across individuals.

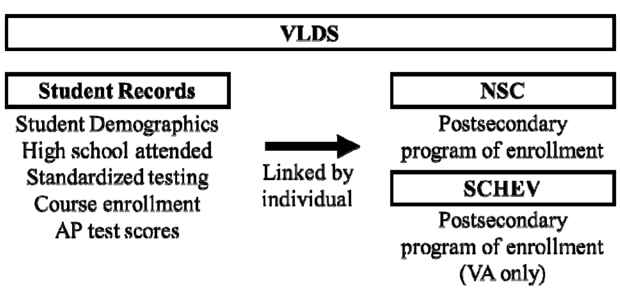

Fig. 1 Linking individuals across data sets.

The presentation of preliminary results will include demographic maps of students going into engineering across the state. In this way, we will depict the geography of engineering enrollment by the demographic variables from the VLDS.

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