



## Poverty and Guidance: Challenges and Opportunities in Mathematics Preparation for Engineering

### Dr. Eliza Gallagher, Clemson University

Dr. Gallagher is an Assistant Professor of Engineering and Science Education at Clemson University, with joint appointments to Mathematical Sciences and Education & Human Development. Her research interests include student cognition in mathematics, development of teacher identity among graduate teaching assistants, and curricular reform to foster diversity and inclusion in STEM fields. She is co-PI on an NSF INCLUDES Design and Development Launch Pilot, "Statewide Coalition: Supporting Under-represented Populations in Precalculus through Organizational Redesign Toward Engineering Diversity (SC:SUPPORTED)," Award #EEC-1744497.

### Anna Marie Vagnozzi, Clemson University

Anna Marie Vagnozzi is a Graduate Research Assistant in the Department of Engineering and Science Education at Clemson University. She holds a master's degree in Mathematical Sciences from the Clemson School of Mathematical and Statistical Sciences.

### Mrs. Rachel Lanning, Clemson University

Rachel Lanning is a Graduate Research Assistant in the Department of Engineering and Science Education at Clemson University. Her disciplinary background is in mathematics with a mathematics Master's degree from Georgia Southern University. Her research interests include well-being and departmental culture as it pertains to STEM graduate students.

### Dr. D. Andrew Brown, Clemson University

Dr. Andrew Brown obtained his PhD in Statistics from the University of Georgia, after which he joined the Department of Mathematical Sciences at Clemson University. In addition to collaborative work, his methodological research interests are in Bayesian statistical models with applications in uncertainty quantification and neuroimaging.

### Dr. Christy Brown, Clemson University

Dr. Christy Brown is a Clinical Assistant Professor of Quantitative Methodology in the Department of Education and Human Development (EHD) at Clemson University. She is the director of the EHD Quantitative Clinic, which provides statistical support to educational researchers.

### Dr. Kristin Kelly Frady, Clemson University

Kristin Frady is an Assistant Professor at Clemson University jointly appointed between the Educational and Organizational Leadership Development and Engineering and Science Education Departments. Her research focuses on innovations in workforce and career development in educational, community, and industry contexts, specifically focusing on middle skills, STEM, and community college applications.

### Julia Machele Brisbane, Virginia Polytechnic Institute and State University

Julia Brisbane is a Ph.D. student in the Engineering Education Department at Virginia Tech and an M.S. student in the Virginia Tech – Wake Forest University School of Biomedical Engineering and Sciences Engineering. She received her Bachelors of Science in Bioengineering from Clemson University. She was previously an undergraduate research assistant in Clemson University's Engineering and Science Education Department. Her research interests include undergraduate research experiences, diversity and inclusion in engineering, and intersectionality.

### Dr. Michael A. Matthews P.E., University of South Carolina



Professor Matthews received his PhD from Texas A&M University in 1986. He was a member of the faculty at the University of Wyoming from 1987 to 1993, and has been at the University of South Carolina since 1994. He currently is Senior Associate Dean for Research and Graduate Programs and Vice Dean in the College of Engineering and Computing

**Mr. Joseph Murphy, University of California, Los Angeles**

Joseph Murphy is a graduate student of Sociology at the University of California, Los Angeles whose research interests include the mobilization of college knowledge, and the role of institutional agents in promoting college access to STEM programs. He received a B.S. in Sociology from Clemson University.

**Dr. Khushikumari Patel, Clemson University**

Khushikumari Patel received her PhD in Engineering and Science Education at Clemson University. Her research focus is on student conceptualization in General Chemistry. She also works on projects related to student behavior and factors affecting conceptualization. She received her undergraduate degree in Chemistry with a minor in secondary education from Millsaps College. She also holds a secondary license to teacher chemistry and general science for middle and high schools in the states of Mississippi and Tennessee. She received her master's degree in Inorganic chemistry from Tennessee State University.

**Dr. Aubrie Lynn Pfirman, Lander University**

Aubrie L. Pfirman is an assistant professor of Chemical Education at Lander University. Her research explores the relationships of underrepresented students in the sciences with advisors and mentors, quality STEM programs, and various classroom techniques for conceptual gains. Dr. Pfirman received a B.S. in Chemistry and an Instructional I Certification in Secondary Education from Misericordia University, and her M.S. in Chemistry and Ph.D. in Engineering and Science Education from Clemson University.

**Dr. Robert J. Rabb P.E., The Citadel**

Robert Rabb is a professor and the Mechanical Engineering Program Director at The Citadel. He previously taught mechanical engineering at the United States Military Academy at West Point. He received his B.S. in Mechanical Engineering from the United States Military Academy and his M.S.E. and PhD in Mechanical Engineering from the University of Texas at Austin. His research and teaching interests are in mechatronics, regenerative power, and multidisciplinary engineering.

**Mr. Richard H Roberts Jr, Florence Darlington Technical College**

Mr. Roberts has extensive experience in all sectors of industry and education. He currently is the Managing Director for the South Carolina Advanced Technological Education Center at Florence Darlington Technical College, Florence S.C. As Managing Director, he manages day to day operations, grants writing and a large industry consortium, including an internship program for students in advanced technology programs. He currently is Co-principal investigator on three separate NSF Advanced Technological Education Program grants that address the needs for technician education at two year colleges across the country. Prior to his current position at FDTC he served as Director of Job Placement and Career Services at the Community College of Allegheny County, Pittsburgh, Pa where he worked with industry and helped place students in internships, apprenticeships, and jobs across a multi-campus system serving 20,000 credit students. He also served Vice President of Family/Children's Services and Program Development for Lifesteps, Inc a large non-profit in the Western Pennsylvania area. He has served in various executive level management/supervisory positions within non-profit organizations, private industry and education including Penn State University and as a User Analyst/Subject Matter Expert for Lockheed Martin IMS. He has held the held appointed and elected positions of Legislative Affairs Chair for the Pennsylvania Association of Educational Program Personnel, Chairman, Zoning Hearing Board in his municipality from 2003-2007, Elected to the position of School Director in the South Butler County School District (Knoch H.S.) and held that position continually before completed his school board tenure in December 2015. Appointed and served on the Executive Board of the Pa. Midwestern Intermediate Unit #4 and recently held a seat on the West Jefferson Hills, Pa Chamber of Commerce executive board.



Mr. Roberts holds a Bachelor's degree in Police Administration from Eastern Kentucky University, and a Master's degree in the Administration of Justice from Shippensburg University. He has also completed 18 post graduate credits toward his doctorate degree while attending Point Park University, Pittsburgh, Pa.

## **Dr. Ronald W. Welch P.E., The Citadel**

Ron Welch (P.E.) received his B.S. degree in Engineering Mechanics from the United States Military Academy in 1982. He received his M.S. and Ph.D. degrees in Civil Engineering from the University of Illinois, Champaign-Urbana in 1990 and 1999, respectively. He became the Dean of Engineering at The Citadel on 1 July 2011. Prior to his current position, he was the Department Head of Civil Engineering at The University of Texas at Tyler from Jan 2007 to June 2011 as well as served in the Corps of Engineers for over 24 years including eleven years on the faculty at the United States Military Academy.

## **Dr. Anand K. Gramopadhye, Clemson University**

Dr. Anand K. Gramopadhye's research focuses on solving human-machine systems design problems and modeling human performance in technologically complex systems such as health care, aviation and manufacturing. He has more than 200 publications in these areas, and his research has been funded by NIH, NASA, NSF, FAA, DOE, and private companies. Currently, he and his students at the Advanced Technology Systems Laboratory are pursuing cutting-edge research on the role of visualization and virtual reality in aviation maintenance, hybrid inspection and job-aiding, technology to support STEM education and, more practically, to address information technology and process design issues related to delivering quality health care. As the Department Chair, he has been involved in the initiation of programmatic initiatives that have resulted in significant growth in the Industrial Engineering Program, situating it in the forefront both nationally and internationally. These include the Online Master of Engineering in Industrial Engineering Program, the Endowed Chairs Program in Industrial Engineering, Human Factors and Ergonomics Institute and the Clemson Institute for Supply Chain and Optimization and the Center for Excellence in Quality. For his success, he has been recognized by the NAE through the Frontiers in Engineering Program, and he has received the College's Collaboration Award and the McQueen Quattlebaum Award, which recognizes faculty for their outstanding research. In addition, Dr. Gramopadhye serves as Editor-in-Chief of the International Journal of Industrial Ergonomics and on the editorial board for several other journals.

# **Poverty and Guidance: Challenges and Opportunities in Mathematics Preparation for Engineering**

## **Abstract**

The Statewide Coalition Supporting Underrepresented Populations in Precalculus through Organizational Redesign Towards Engineering Diversity (SC:SUPPORTED), a Design and Development Launch Pilot funded under the National Science Foundation INCLUDES program, is a coalition of secondary districts and postsecondary institutions throughout South Carolina that have joined together to address the systemic issue of mathematics preparation and placement for students pursuing or intending to pursue engineering degrees.

In Year One of the project, we used individual data for all 21,656 first-year STEM-intending students enrolled in a public two- or four-year postsecondary institution with ABET-accredited engineering programs in the state to identify specific pathways with high rates of placement in or above calculus, pathways with balanced rates of placement in/below calculus, pathways with high rates of placement below calculus, and “missing” pathways: ones that produced disproportionately few engineering-intending students. From the pathways analysis we identified target locations for focus groups to identify factors that do not readily appear in institutional data, such as the impact of guidance counselor recommendations in a student’s selection of their last high school math course taken. Broad themes emerging from the focus groups provided additional insight into potential interventions at multiple points along educational pathways. These themes also contributed to both the development of a survey for statewide administration and a follow-up study to develop profiles of school district decision-making with direct and indirect effects on mathematics preparation and major selection of students from that district.

As we conclude Year Two of our launch pilot, in this paper we integrate a subset of results from different aspects of the project to address both quantitative impact and qualitative context of the roles that poverty and guidance play in gaining access to engineering in South Carolina.

## **Introduction**

The SC:SUPPORTED project is based on wide recognition that initial college mathematics placement is a strong predictor for completion of an engineering degree [2, 5, 7, 9, 12]. Many factors associated with mathematical preparation have been previously identified in the literature. Our goal with SC:SUPPORTED was to quantify, qualify, and contextualize both known and

previously unidentified factors within our state in order to provide a framework for testing interventions to broaden participation in engineering and engineering-related fields.

We began by pooling data from all 21,656 first-year students enrolled in engineering and engineering-related fields at the twenty coalition campuses. This provided us with the Post-Secondary Student Census Data. Analysis of that data yielded six locations at which Student Focus Groups (Figure 1) were conducted to uncover previously unidentified relevant factors [6].

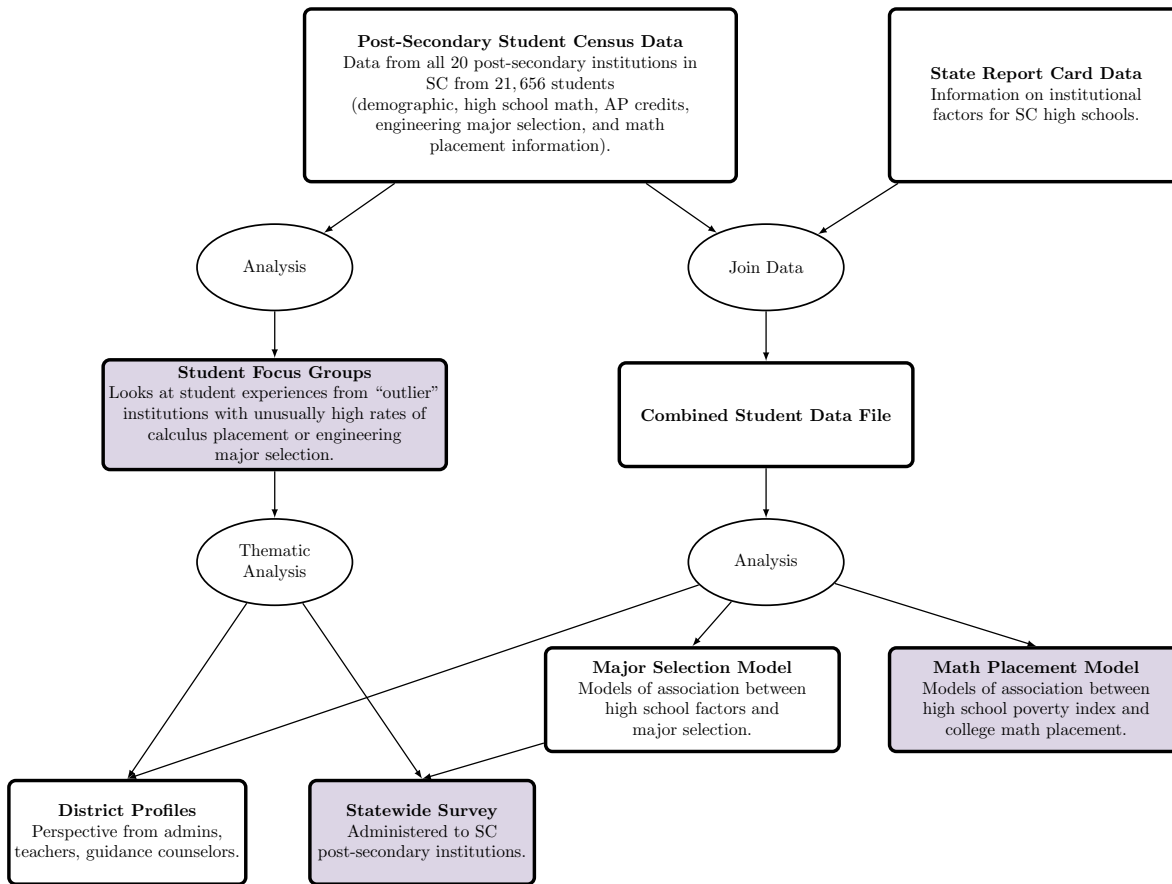
For students within the Post-Secondary Student Census Data who attended high school in South Carolina, we then created a Combined Student Data File that included individual demographic and post-secondary placement information concatenated with high school institutional information drawn from the SC Report Card Data published by the SC Department of Education (Figure 1) [11]. Analysis of the Combined Student Data File allowed us to create models of association between district-level poverty, mathematics placement, and major selection for students from South Carolina in engineering and engineering-related fields [4].

Thematic analysis of the qualitative data from the Student Focus Groups led to development of a Statewide Survey (Figure 1) to quantify the impact of themes identified in the focus groups. Those themes, paired with the models emerging from analysis of the Combined Student Data File, also informed a District Profiles study (Figure 1) in which we are investigating district- and school-level policies and priorities yielding results that depart sharply the predictive models for mathematics placement and major selection.

In this paper, we integrate selected key results from the Student Focus Groups, the Statewide Survey, and the Math Placement Model (highlighted in Figure 1) to describe both barriers to engineering access imposed by poverty and opportunities to support students in overcoming those barriers through timely intervention and guidance. Some of the results integrated here have appeared elsewhere as portions of separate analysis stages, or are currently under review. However, the integration of these specific results from different project stages has not previously been reported elsewhere.

### **Association between Poverty Index and Math Placement**

Throughout the country and world, low socioeconomic status (SES) has profound negative associations with educational opportunities and attainment [1, 10]. It is no surprise that the same holds in South Carolina. In particular, there is a strong association between district-level poverty index and preparation for calculus, as shown in Table 1 [one citation removed for blind review]. Students entering engineering or engineering-related fields from the lowest-poverty schools have an estimated 80% chance of placing into Calculus I or higher. In contrast, students from the highest-poverty schools have an estimated 6% chance of placing into Calculus I or higher. Taken another way, a student entering an engineering program from a high-poverty school in South Carolina has an estimated 94% chance of needing one or more additional semesters to complete the calculus sequence required for an engineering. These rates of mathematics placement are among students who are entering engineering- and engineering-related fields only, and can be presumed to be higher if we were to include all students from all fields.



**Figure 1 NSF INCLUDES Project Overview.** A diagram outlining the stages of the research project. Selected results from highlighted elements of the diagram are discussed in this paper.

Table 1 raises ethical concerns. To improve six-year graduation rates and retention to degree, the calculated option is to focus recruiting efforts on students from low-poverty high schools and minimize enrollment by students from high-poverty high schools. This would cause harm to the populations we are most interested in helping in this study and we stress that these results should not be used to support such a decision. Rather, these results should be used to help stakeholders understand the impact of systemic inequities on individuals so that those inequities can be mitigated.

It is also worth noting that our analysis revealed a few high schools whose actual placement rates were strong outliers for the model. That is, there are high schools in South Carolina with significantly higher percentages of students placing into Calculus I or higher than predicted by the district poverty index. These schools are the subject of a follow-up District Profiles study (Figure 1) exploring administrative decision-making and programmatic implementation that yield outlier results. The data from that study are currently under analysis.

**Table 1:** Predicted proportion of students placing into Calculus I at different district-level poverty indices.

<b>District Poverty Index</b>	<b>Estimated Calculus I+ Placement</b>
5%	0.80
15%	0.72
25%	0.62
35%	0.51
45%	0.40
55%	0.30
65%	0.21
75%	0.15
85%	0.10
95%	0.06

### Exploring the Student Perspective

Concurrent with analysis of the Combined Student Data File, we conducted Student Focus Groups (Figure 1) to identify factors that students perceived as highly influential in their mathematics preparation, major selection, and choice of two- or four-year post-secondary institution. The students were chosen from “outlier” clusters, or locations with much higher or lower rates of calculus placement or engineering major selection than the general trend [6]. Six major themes emerged from the focus groups: familial and fictive kin relationships, family responsibilities, selective attention from high school guidance counselors, peer influence, reliance on technological aids, and curricular mismatching [3, 8]. These themes, together with results from the Major Selection Model, the Math Placement Model, and archival literature, resulted in a statewide survey for distribution at all coalition campuses in Fall 2019.

Significant issues with deployment of the survey resulted in response rate that was below our acceptable threshold for inferential statistical analysis, both for overall number of complete responses ( $n = 542$ ) and for distribution of responses along demographic characteristics such as institutional affiliation, major, and racial/ethnic identity. Descriptive analysis of relevant variables from the survey supports that the themes identified in the focus groups are all reflected in the survey responses. The survey will be re-administered in Fall 2020 with new distribution guidelines to obtain the desired response rate.

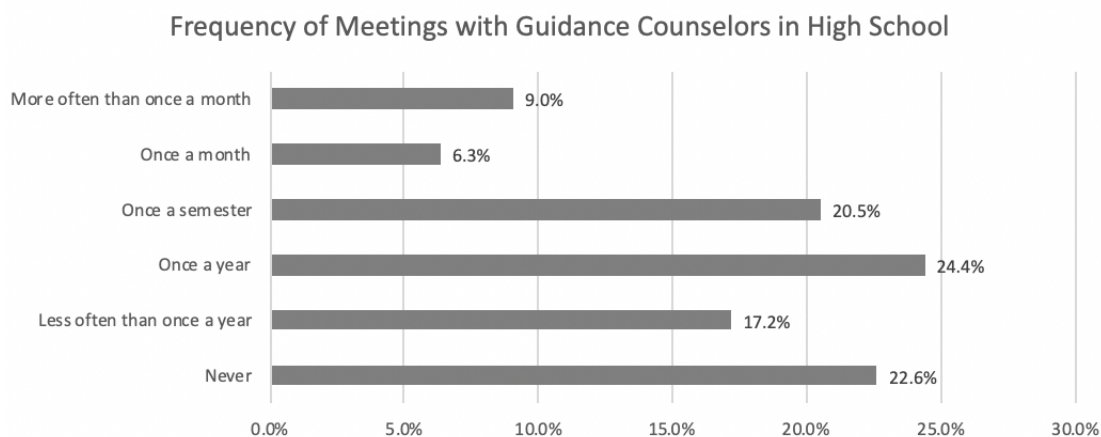
Although we cannot quantify the extent to which the focus themes are reflected within the full student population, much less within key subpopulations, the focus group themes nonetheless yield useful insights into understanding the mechanisms by which district-level poverty index affects mathematics placement at the post-secondary level. We focus here specifically on the role of high school guidance counselors. These results are reported in greater detail as part of a larger analysis elsewhere, but without the integration with the quantitative results in Table 1 [4].

The focus groups revealed strong emotion, both positive and negative, surrounding the role of

guidance counselors in educational attainment and opportunities for students in South Carolina. State law mandates a ratio of 300 students to one guidance counselor and schools with small enrollments may share guidance counselors across multiple schools in the same district. Schools with lower poverty indices have the option of allocating resources to lower the student-to-counselor ratio. These schools also have a higher percentage of families with college-educated parents who provide additional guidance from their own experience navigating college admissions and enrollment.

Students in the focus groups who had entered college from a school with a high poverty index identified several ways in which their interactions with guidance counselors negatively affected their mathematics placement in college. Some of these were directly related to a lack of available resources at the school; others were related to a lack of clear information related to college expectations for admissions and for success in STEM-related fields. These themes formed the basis for several questions on the Statewide Survey.

A 2005 state law mandates that each student in South Carolina discuss an Individual Graduation Plan with a guidance counselor at least once per year starting in eighth grade and continuing through graduation. Within the focus groups it became apparent that this was not occurring in practice in an effective manner. This theme was echoed in responses on the Statewide Survey, with 39.8% of respondents indicated they met with a guidance counselor either never (22.6%) or less than once per year (17.2%) (Figure 2). Nearly a quarter of students (24.4%) met with guidance counselors at the minimum legal rate of once per year.



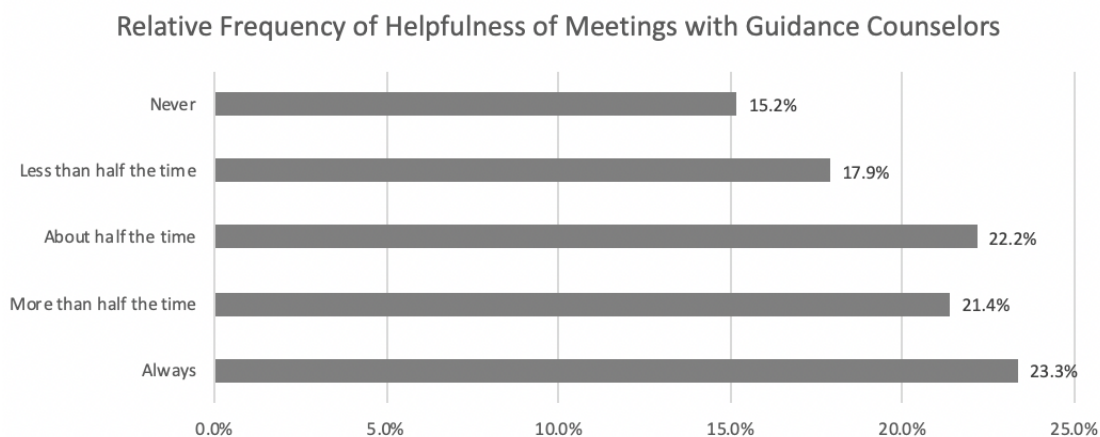
**Figure 2** Frequency of meetings with guidance counselors as reported by students completing the Statewide Survey in Fall 2019 ( $n = 332$ ). Categories reported are as they appeared on the survey.

Meetings with guidance counselors, however, often failed to provide the information students desired. In particular, students in the focus groups expressed frustration over learning too late about college admissions requirements or expectations for mathematics preparation for STEM degrees. In particular, high school graduation requires Algebra I, Geometry, and two additional units of mathematics. College-ready standards require Algebra I, Geometry, Algebra II, and a math course with Algebra II as a prerequisite (typically precalculus). A common theme among



focus group participants at two-year colleges was that they were advised not to take math courses beyond Geometry, even when they indicated an interest in STEM fields.

These perceptions of the value of guidance were reflected in the Statewide Survey, with 33.1% of students responding that their meetings with guidance counselor were helpful either never (15.2%) or less than half the time (17.9%) (Figure 3). Moreover, 51.8% did not learn about expectations for mathematics courses beyond Geometry until 11th grade or later, too late to make curricular adjustments and enter college calculus-ready.

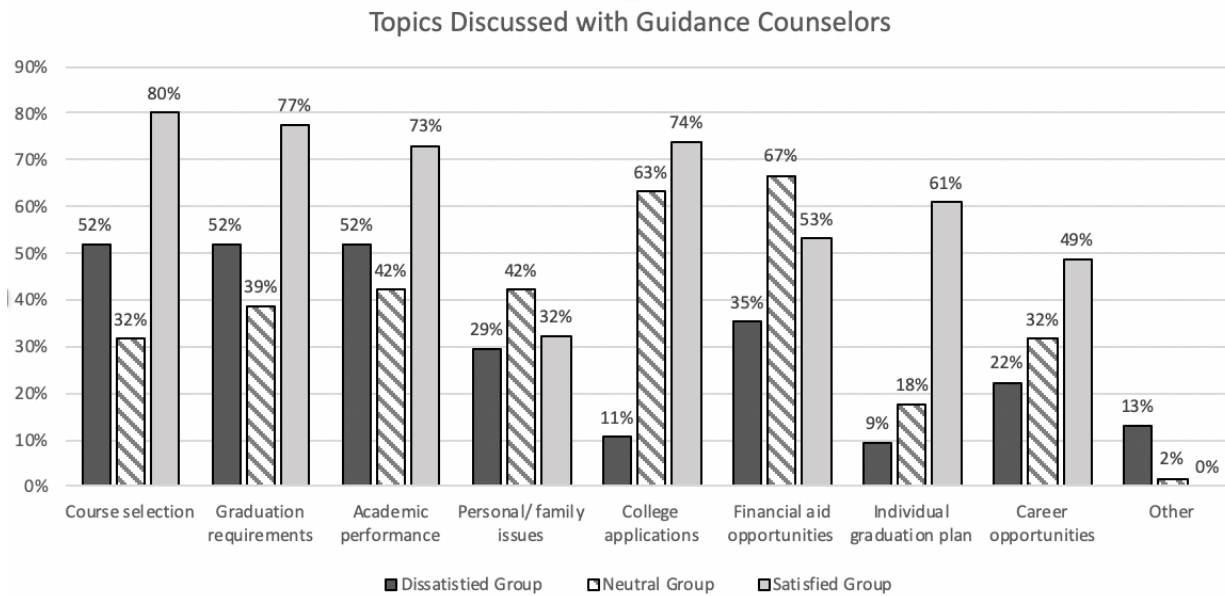


**Figure 3** Relative frequency of helpfulness of meetings with guidance counselors as reported by students completing the Statewide Survey in Fall 2019 ( $n = 257$ ). Categories reported are as they appeared on the survey. This prompt was not presented to the 75 respondents who indicated they had never met with a guidance counselor.

We also asked students who reported that they had met with a guidance counselor at least once to indicate what topics had been discussed with a guidance counselor. The choices were drawn from the focus groups and students could select as many as they wanted. Students who indicated that meetings with guidance counselor were helpful never or less than half the time (the ‘dissatisfied group’) identified an average of 2.75 topics that had been discussed. In contrast, students who indicated that meetings with guidance counselors were helpful more than half the time or always (the ‘satisfied group’) identified an average of 4.99 topics that had been discussed in the meetings. The pattern of topics discussed is also revealing (Figure 4).

Among students who were generally dissatisfied with their meetings with guidance counselors, only 11% indicated that they had discussed college applications, as compared with 74% of students who were generally satisfied with their meetings with guidance counselors. We note that the students completing the Statewide Survey were enrolled in a two- or four-year college, so college applications would have been a relevant topic in all cases. Similarly, 9% of generally dissatisfied students indicated that they had discussed individual graduation plans, as compared to 61% of generally satisfied students.

While we acknowledge the limitations of the data set and our choice not to carry out inferential statistics, it appears from this limited response that discussion of college admissions and individual graduation plans is central to students feeling satisfied with the support they are



**Figure 4** Topics discussed with guidance counselors as reported by students completing the Statewide Survey in Fall 2019 ( $n = 257$ ). Percentages sum to more than 100% as students could select all that applied. The “Dissatisfied Group” consists of the 85 respondents who indicated that meetings with guidance counselors were helpful never or less than half the time. The “Neutral Group” consists of the 57 respondents who indicated that meetings with guidance counselors were helpful about half the time. The “Satisfied Group” consists of the 115 respondents who indicated that meetings with guidance counselors were helpful always or more than half the time. This prompt was not presented to the 75 respondents who indicated they had never met with a guidance counselor.

receiving from guidance counselors. Students want to have more information available to them about graduation requirements, preparation for their intended careers, and college admissions. The role of guidance counselors in providing this information is more critical for first-generation college students than for those with extracurricular access to trusted adults with the navigational capital of having already accessed higher education. We hypothesize that when that information is not provided by guidance counselors early, it plays a critical role in widening the calculus-readiness gap for STEM-intending students along district poverty lines.

In addition to being sources of critical information for decision-making, guidance counselors also serve as both direct and indirect gatekeepers for mathematics courses. Our focus group participants highlighted the role that guidance counselors played in either encouraging students to take more advanced mathematics courses, or in discouraging them from doing so. These themes, again, are reflected in the survey responses we received. Of the students who had access to a precalculus course in high but chose not to take it, 44.1% indicated that a significant reason for not taking the course was that no one recommended it; 13.1% indicated that their guidance counselor actively recommended against taking precalculus.

## **District Profiles**

The central role played by guidance counselors, particularly in the absence of family or fictive family members able to support informed decision-making for STEM careers during high school, indicates that even with limited resources, districts may be able to improve college mathematics placement for STEM-intending students. Other aspects of the project have indicated other critical decision points, such as policies regarding use of educational technology in mathematics courses.

These insights form the basis for the District Profiles follow-up study (Figure 1). In the District Profiles project, we have identified four high-poverty school districts that diverge from the math placement or major selection model in specific ways. We have collected data from semi-structured interviews with district administrators, guidance counselors, and mathematics teachers to determine administrative policies, district programs, and individual approaches that may provide templates for improvement in otherwise similar districts.

## **Next Steps**

We are currently in a no-cost extension of our initial funding and have three specific objectives to complete the original goals of the Launch Pilot:

1. Complete the District Profiles analysis and make recommendations for district-level policies to improve college mathematics placement for STEM-intending students.
2. Redistribute the Statewide Survey in Fall 2020, using lessons learned in 2019 to achieve an acceptable response rate and distribution of responses among key demographic characteristics.
3. Conduct follow-up interviews with specific survey respondents to further understand trends of interest within the limited response data.

## **Discussion**

Analysis of Statewide Survey responses in a successful distribution will provide additional insight into interventions, including development of a structural equation model governing mathematics preparation and major selection within the statewide educational system. However, the Focus Group themes, supported by the limited results of the first distribution of the Statewide Survey, already indicate a clear and accessible intervention point: guidance counselors.

It is our assumption that guidance counselors actively seek the best for the students they advise. With 300 students to advise each year, only 180 school days in which to carry out the advising, and a host of non-academic counseling duties and administrative reporting responsibilities, including academic advising, guidance counselors carry a heavy workload. They must choose how to prioritize their time with each student. The District Profiles analysis will provide insight into district-level policies and information-sharing that lead to productive practices for supporting engineering-intended students in mathematics course selection and preparation for college. Those

practices will then be shared with other districts, while insights from the Focus Groups and Statewide Survey will be shared directly with guidance counselors in high-poverty-index districts through a series of professional development workshops around the state.

The results from our first two years underscore the need to identify causal factors driving systemic inequity, particularly given the strong correlation within South Carolina between socioeconomic status and minoritization along racial and ethnic lines. By designing effective interventions to disrupt the association between district-level poverty index and college mathematics placement, we have the opportunity to broaden participation in engineering, and consequentially reduce wage and wealth gaps within the state.

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