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The Value of Climate in Educational Experiences for Diverse Student Populations within Engineering Disciplines

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ABSTRACT. *In 2016, an NSF S-STEM grant was awarded to explore the connection between student support networks and success within collegiate STEM field majors. For this on-going diversity study, promising students with low socio-economic status were selected from a pool of low socio-economic status applicants that were denied admission straight into engineering, but given admission into the university. These Rising Scholars were invited into a scholarship program based upon the quality of their support networks and their readiness for higher education. Local research on institutional efficacy supported the concept that student success and satisfaction with the collegiate experience were directly related to how welcome and comfortable the student felt within their chosen academic field. The students need to feel that they are part of a larger community that values them and their contributions. Advocacy organizations and smaller engineering schools, like Agricultural & Biological Engineering, do a good job creating this welcoming climate for their students. The Rising Scholar program was designed to create a local, familial cultural reference point for the students and utilize existing successful elements of the local university environment. Multiple experiential elements, professional communication exercises, and social opportunities were provided to enhance student skills and contact networks. The students were provided numerous chances for interaction and were continually reminded about networking strategies. Initial retention and GPA data support the conclusion that these students can be very successful in a highly ranked, R1 institution when provided with sufficient mentoring and means to reduce the financial burden of attendance.*

Keywords. support networks, socioeconomic status, bias, admissions, NSF S-STEM.

Introduction

S-STEM disciplines, and engineering specifically, have a retention issue which has colloquially become known as 'the sieve'. Far more students enter engineering than complete it at most highly-regarded institutions. Larger schools within the university have bigger problems, and the likely cause of the problem is the lack of interpersonal attention and sense of community within larger departments. Smaller departments and university advocacy organizations have long understood the value of a more intimate, personal climate for nurturing successful students within the collegiate environment. This deliberate, focused mentoring approach to high-touch, undergraduate counseling was incorporated into the planning for the 2016 NSF S-STEM grant #1644143: *Rising Scholars: Web of Support used as an Indicator of Success in Engineering*.

This grant funded a combined research and scholarship program examining the effect of a network of positive adult supporters on the collegiate success metrics of low socio-economic status (SES) students seeking a STEM education. Students who meet the low SES criteria and are seeking higher education have become known as 'Rising Scholars' (RS) (Kent State University, 2021; Stanford University, 2020). This work is vital to equity in access to higher education, because potential students fitting this classification often times have significant difficulties reaching their collegiate educational goals (Cooper & Berry, 2020) and face issues that traditional students do not have to contend with (Holland, 2014). These students are many times working much harder than their peers simply to be in college, and they clearly understand the positive life-long economic ramifications of completing a Bachelor's degree (Smith et al., 2020). Prospective applicants for this program were selected on the basis of the strengths of their support networks and received an annually renewing scholarship to place them on an equal footing with majority students. Selected students were required to move through a 'best practice' path for STEM majors and provide data about their experiences. This paper will discuss the background regarding the creation of the program, provide a review of the literature on the effect of climate on educational outcomes and observed successes, deliver a detailed description of the selection process and the overall program, and show some initial results for the first classes of students.

Background on the Problem

Public land grant colleges were originally intended to be institutions of higher education that supported the masses being educated in the 'practical and mechanical arts'. Unfortunately, the very success of these universities has made it more difficult for the first time / first-in-family students to matriculate into these schools, particularly studying high-paying STEM majors. It has been shown that low SES students have the highest chance of graduating from these college, but the actuality is only about 3% of the lowest quartile end-up in a top tiered college (Kahlenberg, 2004). Many of these low SES students then contend with situations that are unique to their background and social status (Anderson & Douglas-Gabriel, 2016; Bowen & Bok, 1998). Colleges facing voluminous numbers of admissions decisions have begun depending more heavily on standardized test results which have been proven to penalize these same students (Dixon-Roman et al., 2013). This results in many otherwise qualified, young individuals being prevented from having access to the very careers which could elevate their societal status (Bailey & Dynarski, 2011).

The overall predictive ability of the standardized tests used by many universities in picking eventual successful graduates for admission is poor and significantly contributes to the present societal inequity in higher education outcomes (Brunn-Bevel & Byrd, 2015; Boaler, 2003). Studies conducted by the Minority Engineering Program (MEP) at Purdue University demonstrated that at least for under-represented minority students, high incoming test scores were not necessary for ultimate success in engineering (Baldwin et al., 2021a). Figure 1 shows the results of this review, incorporating five years of recent institutional data. Clearly, many underrepresented minority students have what Duckworth et al. (2007) has termed 'grit' and are successful without either high test scores or high school GPA. The sense of community and support provided by the advocacy organization's personnel seems to be far more critical to maintaining the students' persistence and goal orientation.

Peterson (2016, 2010) supports this notion, based upon studies done with native peoples in Alaska. He suggests that the crucial background element to foretell academic success is the quantity and quality of the young person's adult support network. Peterson works extensively in professional training for K-12 instructors, and his techniques are being used by teachers and school administrators in all 50 states to improve the lives of their underperforming students. He has successfully worked with disadvantaged students around the world to show them how to develop resilience in their lives and improve their adult support networks. Other authors have noted this correlation with supporting adults. The National Scientific Council on the Developing Child (2015) has suggested that one supportive adult is necessary in a young person's life for psychological well-being and academic support, but based upon his experiences, Peterson suggests that five interested adults are actually needed within a young person's life in order to provide the care and guidance to successful mature them into a young adult.

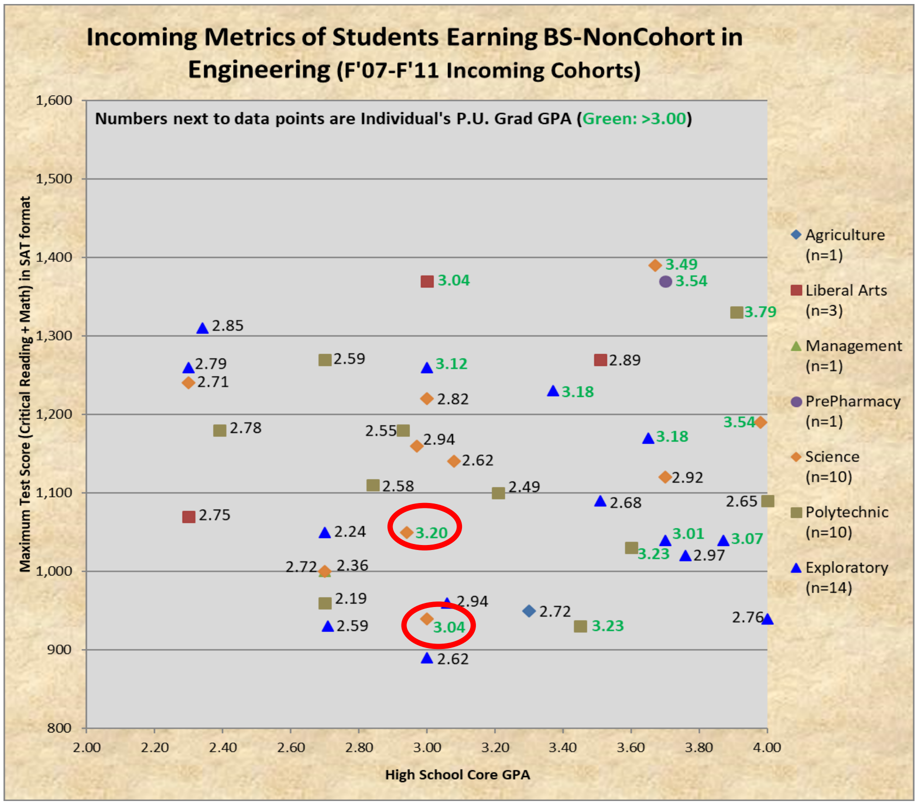

Figure 1 – Purdue University engineering graduation GPAs plotted against high school core GPA and maximum equivalent test scores (SAT critical reading + math) (Baldwin, Booth Womack, LaRose, Stwalley, & Stwalley III, Selection methodology for membership in an NSF S-STEM program, 2021a).

Finally, it has been observed that students' feelings about their collegiate experience and their persistence toward graduation were strongly influenced by presence of faculty and staff members who took a deeper interest in their academic careers (Gallup, Inc., 2014). Having a professional take notice of them, treat them with respect, and interact with them in a collegial manner is vital to shaping both their view of the experience and the self-esteem as a professional. The common element in these examples is the human connection that the individual student gets with adult mentors that can provide them with the benefit of their wisdom and experience. Key factors in crafting an environment favorable to the development of mentoring relationships in academia are an openness on the part of faculty and staff to be available for interaction with students, and recognizing that not all personalities mesh with others, frequent opportunities to facilitate multiple interactions with numerous people. Simply put, the climate of the learning environment is foremost factor in whether a student enjoys and values their collegiate education.

Review of the Effect of Climate & Observed Successes

Climate has been clearly demonstrated to affect non-white and non-traditional students' retention. Oseguera & Rhee (2009) point-out that climate has been overlooked for numerous years in studies of retention metrics. The common academic response to issues of population inequity within higher education retention was that the non-succeeding students somehow weren't ready for college. Yet, Banks & Dohy (2019) found in their review of underrepresented retention in higher education that numerous studies indicated that unsuccessful students clearly stated that they felt out-of-place or unwelcome. The cultural elements of the academic world that create this feeling may not be directly antagonistic toward the unsuccessful student, but without a support network experienced in higher education to guide the student, it can certainly feel impersonal. Research-driven faculty priorities, high student-to-instructor ratios, not seeing professors that look like them, and the general lack of training in pedagogy by faculty members can create the impression of an uncaring institution to an underrepresented minority student. These factors are clearly present within the large, successful departments that are forced to conduct big classes. It is not unreasonable to extrapolate these negative feelings into the low SES students who share some similar characteristics with underrepresented minority students. Problematic factors for these RS students could include needing to work to afford to be in school, being the first in the family to matriculate into higher education, or being a first generation American. Few would argue that it is difficult to remain focused on a long term goal when you are questioning whether the path you are traveling is the right one for you.

Love (2009) concurs with climate being the biggest issue in underrepresented retention, but he further clarifies the issue by concluding that a lack of inclusion within school activities was the single biggest reason for the unfavorable climate. Doan (2011) comes to a similar conclusion from the opposite perspective. Involvement in student organizations and activities is vital to the retention of non-majority students and second only to a favorable climate for the overall retention of students. If the student activity involves similar peer group members, its effectiveness for collegiate retention is increased. Experience from the Purdue MEP supports this conclusion for both retention and improved GPA (Stwalley et al., 2015), and it is hereby acknowledged that significant inspiration for the family atmosphere and inclusive environment of the RS program comes from the historical best practices of Purdue MEP for underrepresented advocacy.

Banks & Dohy (2019) conclude from their review of the existing literature on minority retention that while seemingly intractable difficulties with underrepresented students in higher education do exist and persist, the best results are achieved by acknowledging the visible problems and attempting to do something about specific issues. If large school size and a lack of student involvement represent the two largest negative retention factors, then initiatives can be developed or included within student life activities to address those concerns. The small and modest sized engineering departments do this fairly well, and the Purdue Agricultural & Biological Engineering (ABE) department was the model for the academic elements of the RS program. This department has always maintained outstanding student-to-instructor ratios, and it has remained squarely focused on the big challenge issues that attract modern students into STEM disciplines (National Academy of Engineering, 2021). The ABE department has a strong history of providing course materials and projects illustrating communal goals, and this has been shown to be beneficial to women, underrepresented minorities, and first generation college students (Boucher et al., 2017). Multiple RS students have utilized ABE for their summer research components, even though their academic home was elsewhere (Baldwin et al., 2021b). This close proximity to ABE faculty and ABE projects has resulted in one RS student proposing to change majors from a larger school into ABE.

The investigators responding to the NSF call wanted to design a high-touch program for low SES students that would improve their chances for a successful journey through higher education into a professional career and test their outcomes against the general engineering population. Scholarships were provided at roughly half the estimated cost of attendance, and these funds were renewable, based upon continued good standing with the program. The social climate model for the program was crafted to resemble the close-knit family environment fostered by the Purdue ABE and MEP organizations. The defined student pathway through the institution utilized several existing and proven campus program offices for research and professional practice activities. Seminars and social events were utilized to provide reflective opportunities and keep the cadres together and communicating throughout the year. Funding was sufficient to take 20 RS students longitudinally through their undergraduate studies, and survey instruments and interview questions were developed to access the students' support network, their learning efficacy about mentoring, and their general experiences within high education.

Selection Process & Program Description

Three years of recruitment were needed to fill the cadres for the RS program. Unfortunately, the admissions pathway into the institution changed in ways that affected recruiting students into the program each year along the way. The pre-screening process typically began with a professional staff member reviewing the applications of those students for three criteria: 1) completed or enrolled in two of three AP courses in Chemistry, Calculus, or Physics; 2) having a core GPA of 3.00 or above; and 3) having a SAT(CR/M) greater than or equal to 1000. Applicants who were at or near to these criteria had their college application examined by the staff member. Students applications were then split into appropriate candidates and those that did not seem to be good matches for the criteria. The appropriate candidates were asked to confirm their interest by providing contact information in an online survey.

The final selection process utilized a written pre-analysis and an on-campus interview with the selection committee of: one faculty member, one advocacy program director, and one professional staff member. A written survey looking for positive traits was given to quantify how much determination the student possessed, how large was their support network, and how they used their support network. This survey was designed using a 12-question grit scale to develop a measure of how determined the applicant was in completing their collegiate goals (Duckworth, 2007). The survey used a condensed version of Derek Peterson's 'Phactors of Support', which asked about people in the applicant's life that provided support (Peterson, 2016). The applicant listed the individual, how the individual was related to them, and what types of support the adult provided. The applicant also wrote an essay about an experience that illustrated the support of one of the adults listed in their network. Students satisfactorily completing the application were invited to campus with their parents for a "Rising Scholar Day on Campus" and oral interview. This interview was created by an Engineering Education department faculty member and allowed the committee to determine:

- what things the student had done to determine that engineering was the right career choice for them;

• that they had a realistic understanding about the difficulties in obtaining an engineering degree;
• that they had previously overcome doubters to achieve a goal; and
• that they could ask for help when they struggled.

The RS Program was planned to be a ‘mentor-rich’ pathway through the undergraduate academic world for students not having a family history of collegiate experiences, which incorporated some known best practice paths through higher education. Many of these elements were developed from association with the Minority Engineering Program. This program traces its history of 45 years to the early establishment of programs within the College of Engineering to increase underrepresented minority representation and provide students access to the many opportunities available to them. These activities have included events designed to foster camaraderie and provide participants with openings to engage with an expanded professional network. Admitted RS students were expected to attend the Engineering Academic Boot Camp during the summer prior to beginning their freshman year and attend an orientation seminar for incoming students during the fall term. This program is primarily designed to help set the level of performance expectations for collegiate workloads. During the summer before their sophomore year, Rising Scholar students are enrolled in the Louis Stokes Alliance for Minority Participation (LSAMP) program to work in an on-campus faculty member’s laboratory assisting their graduate students and post-docs (Purdue University, 2020a). The LSAMP office reaches out to interested professors to determine if they were hiring students for the summer and if not, provided a research project that could be of interest to the student. The LSAMP program provides potential support network contacts and shows how the organization and flow of work within a modern research laboratory work. The sophomore seminar concentrated on communication skills and career selection.

During the summer before their junior year, students typically worked their own research project in a Multidisciplinary Engineering Research Fellowship (MERF). The MERF experience was designed to resemble the senior capstone experience included in most STEM majors and provide a foreshadowing of the same project management and people skills necessary to be successful in industry (Stwalley, 2017; Stwalley, 2016). The focus of the junior seminar shifted toward employability and the value of work experience in enhancing full-time employability (Purdue University, 2020b). RS students are to hold an internship prior to their senior year to gain professional time within the workplace and improve their employability metrics (Haddara & Skanes, 2007; Stwalley, 2006a; Stwalley, 2006b). The rationale and value of the experiential experiences for the RS students are more thoroughly explored in Baldwin et al. (2021c). The RS senior seminar was primarily devoted to helping students receive an offer for a professional entry-level position. Oral and written communication exercises were spaced throughout the RS program to encourage reflective consideration of the experiences and hone needed skills for entry-level employment (Bolton, 2006).

Initial Results

The demographic break-out of the 21 Purdue students recruited to be members of the Rising Scholars program cohorts was:
Gender: 9 - female and 12 - male;
Residency: 18 - residential and 3 - non-residential;
Ethnicity: 14 - Hispanic (1 with American Indian identity);
Race: 3 - Black or African-American;
4 - two or more race (3 with Black identity and 1 with American Indian identity);
First Generation: 11 - students; and
Support Individuals: 6.2 – average number for each student coming into the program.

The RS program outcomes were initially determined by examining college performance and retention/graduation to other similar students. A matched pair analysis was utilized to measure the performance of each RS with a direct-admit Engineering (ENGR) student and a student that had been moved into another major, Exploratory Studies (ES), during the university application process. The ES program was designed for students who either didn’t know what major they wanted or did not make it into their desired major. This program allowed students two years to explore options and take classes without a chosen major. Ethnicity, gender, residency, test scores, high school metrics, original desired major, and first semester courses were used to determine matching students. The output variables compared between the groups each semester were cumulative GPA, credit earned, and retention.

Figure 2 provides data on the first-year retention of all three incoming years (n=21). It is of particular interest that all of the RS remained in school after their first year, and none had been dropped. One and two students had been dropped in the ENGR and ES groups, respectively. The students remaining in Exploratory Studies were approximately equal between the RS with their peers in ES (RS: n=11 vs ES: n=10). The number of RS who had moved into engineering was over double the number of students making that move from the ES group (RS: n=7 vs ES: n=3). A comparison of the RS against the ES students who were retained in Engineering majors was performed with a Chi-squared test to provide a metric counting all students who remained in exploratory or had moved into an engineering degree. There were 18 for the RS and 13 for the ES. This comparison showed the RS students were retained within major at a statistically higher rate than the ES students ($X^2(1)=3.079$, $p=0.040$). Second-year retention of the first two cohorts of students (n=15) was also compared. These data are shown in figure 3. No RS had been dropped, and the RS students were more successful than their ES peers in moving into engineering majors (RS: n=9 vs ES: n=5). One engineering match student has been dropped and had not returned to the university. There was no statistical significance found between groups for the second-year retention metrics.

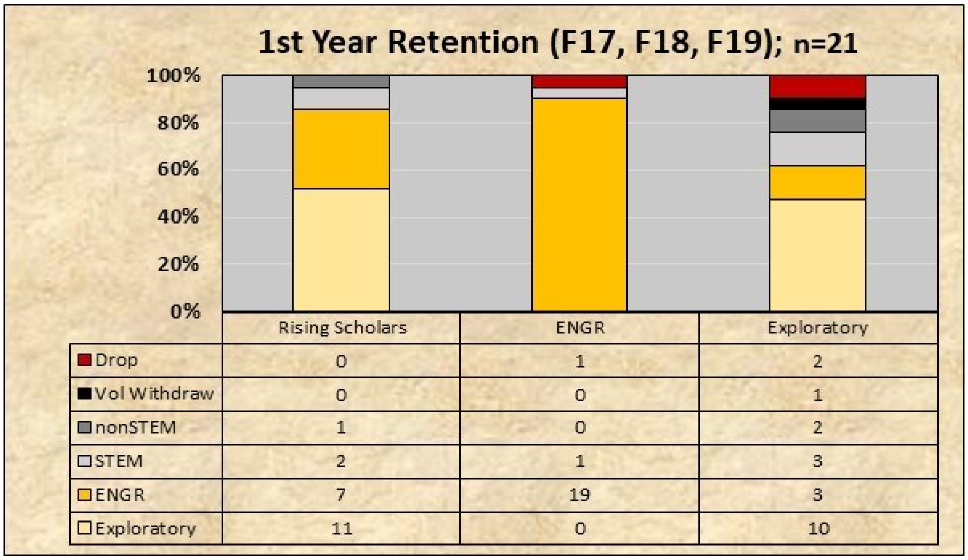

Figure 2 - First Year Retention between Rising Scholars and matched students starting in Engineering and Exploratory Studies.

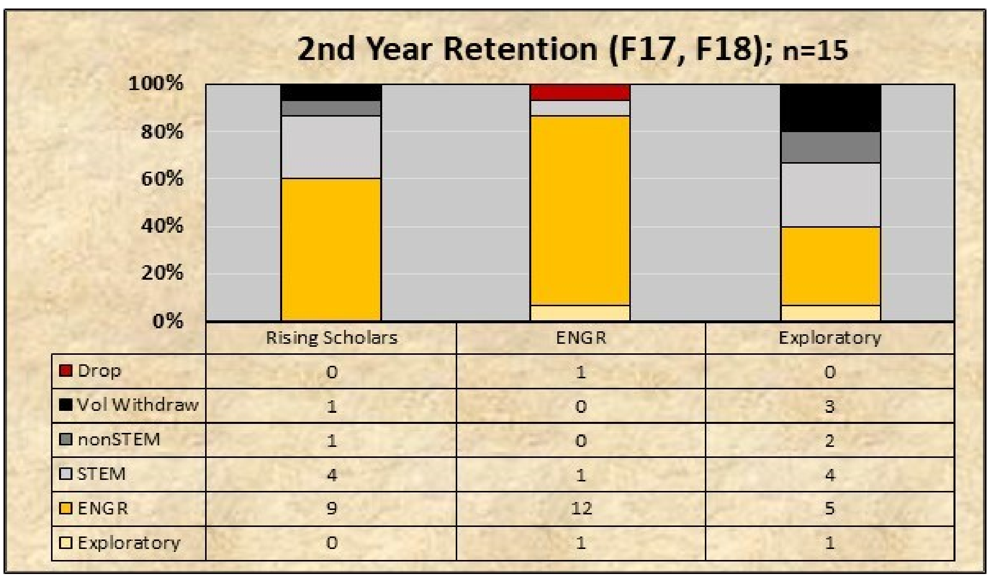

Figure 3 - Second-year retention comparison between the Fall 2017 and 2018 cohorts of Rising Scholars, Engineering, and Exploratory students.

Table 1 compares the cumulative GPA at the end of each year between the same groups. For cumulative GPA, the RS students were above both their Engineering and Exploratory peers for the first-year comparison by a statistically significant margin (RS:ENGR, $t(40)=2.306$, $p=0.013$; RS:ES, $t(40)=2.052$, $p=0.024$). The second year GPA comparison resulted in the RS showing statistical significance over the matching engineering cohort as well (RS:ENGR, $t(28)=2.430$), $p=0.011$). There are not enough cases to statistically compare third year grades. Table 2 presents cumulative credits earned at the end of each year. Little difference is seen between groups, since the university works very hard for students to earn 30 hours of credit each year. These values also count the credit that the student brought into the university from AP, online, and transfer credit course sources. A more detailed examination of the preliminary results of this work can be found in (Baldwin et al, 2021d).

Table 1 - Cumulative Grade Point Averages earned at the end of each year compared between the Rising Scholars, Engineering, and Exploratory students.

		1st Year (n = 21)	2nd Year (n=15)	3rd Year (n = 6)
F17	Rising Scholar	3.21	3.25	3.26
	Engineering	2.96	2.82	2.94
	Exploratory	2.94	2.94	3.10
F18	Rising Scholar	2.80	2.88	
	Engineering	2.57	2.62	
	Exploratory	2.51	2.59	
F19	Rising Scholar	3.33		
	Engineering	2.48		
	Exploratory	2.75		
AVERAGE	Rising Scholar	3.07	3.03	3.26
	Engineering	2.66	2.70	2.94
	Exploratory	2.70	2.73	3.10

Table 2 - Cumulative Credits earned at the end of each year compared between the Rising Scholars, Engineering, and Exploratory students.

		1st Year (n = 21)	2nd Year (n=15)	3rd Year (n = 6)
F17	Rising Scholar	47	81	113
	Engineering	51	84	115
	Exploratory	47	81	111
F18	Rising Scholar	45	74	
	Engineering	38	66	
	Exploratory	35	59	
F19	Rising Scholar	37		
	Engineering	32		
	Exploratory	40		
AVERAGE	Rising Scholar	44	77	113
	Engineering	40	73	115
	Exploratory	40	68	111

Conclusions

The preliminary data are strongly suggestive that students without traditional incoming selective metrics, but having strong support networks that hold high expectations for their academic work, can outperform students with traditional metrics. Both retention and GPA are significantly better than the selected matched pair groups, and although some RS students have transitioned into non-STEM majors, twenty of twenty-one initially selected students remain at the university. The first cadre had its first graduate this spring, and the balance of the initial group are on-track to finish within a year.

The investigators are currently examining the feasibility of increasing the number of students and cooperating institutions. The initial indications from the data are too encouraging for these driven students to be blocked from higher education through inaction. The Rising Scholars were selected using their preliminary knowledge of network support and their desire to pursue a STEM career. They were directed onto a defined collegiate path that was heavily oriented toward experiential experience and professional network development to ensure that sufficient career opportunities would be available for them post-graduation. Most importantly, they have been given the time and support to mature and adapt in an unfamiliar system. The nurturing environment, the social contact, and the directed mentoring commonly found within effective and cohesive advocacy organizations, like the Minority Engineering Program and the small, specialized Agricultural and Biological Engineering department has turned these Rising Scholars into confident young professionals who will undoubtedly make a positive contribution in society.

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