Using Support Networks as a Predictor of Success for STEM Degrees: Preliminary Results Detailing a Selection Process for Test Subjects Engaged in a Longitudinal Study of Low Socio-Economic Status American Undergraduate Students

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Abstract—This study follows the development and execution of a selection process for participants in a National Science Foundation S-STEM grant program for low socio-economic students. The primary research question in this long-term work is whether students from low socio-economic status backgrounds possessing lower incoming metrics can successfully pursue a STEM degree with the help of a web of supporting adults. This paper details the development of a metrics-based selection process that looked at sufficient traditional academic qualifications and the amount of support that students had from adult mentors. Results from a five-year study of underrepresented minority students who had previously succeeded in earning an engineering degree, even though they were not originally admitted into engineering, were used to guide the establishment of quantitative criteria. The selected students met acceptable academic standards, but the selection process uniquely asked students to identify the members of their support network and how they used this support to succeed in life. The selection process for this program culminated in an on-campus interview. The high school metrics for the selected students were found to be significantly lower than their engineering peers, but the average number of anchor/mentors that were identified was 6.2. These students are currently outperforming general admit students in their selected fields.

Keywords—support networks, socio-economic status, bias, admissions, higher education

1 Introduction

The question of who has the right to attend higher education has been a serious point of discussion since the beginning of the United States. Thomas Jefferson felt that if the genius that comes from parents too poor to further the education of their children could be cultivated, then our population would have twice to three times the "mass of mind" of other countries [1]. John Adams agreed and stated, "Laws for liberal education of youth, especially of the lower class of people, are so extremely wise and useful, that to a humane and generous mind, no expense for this purpose would be thought extravagant" [2]. Nothing in these early statements by Jefferson and Adams has changed significantly today, and modern-day admissions decisions into higher education should be compared with a long-term investment in human and social capital [3].

The current admission processes in top-tier American institutions heavily utilize standardized test scores as a metric to compare and rank applications. While class offerings and student grading methodologies vary widely across high schools in the United States and abroad, under this standardized testing system, potential collegiate students will have taken the same tests during their high school career. The SAT and ACT tests would seem to provide common metrics with which to analyze these applicants, and Bastedo presents several ways that these tests, in conjunction with student essays, can be utilized to compare against the applicant's peers and used to evaluate individual determination and potential academic success [4] [5] [6]. However, research has shown that a vast array of factors contributes to student performance in academic settings, and the equity of these high-stakes tests is now being seriously questioned [7] [8] [9]. High school metrics and standardized tests are increasingly criticized for their inability to predict college success across diverse and underserved student groups [10]. Even the College Board acknowledges that SAT scores have a diminished correlation with second year retention compared with first year grades [11].

The students most severely affected by equity problems in standardized testing are generally of low socio-economic status (SES) [12]. The term, 'Rising Scholars' (RS) has become popular as a designator for first generation, low-SES, and/or students of color in education [13] [14]. This paper will examine work on developing and utilizing alternative evaluation methodologies that seem to better predict which of these RS students can succeed in an undergraduate science, technology, engineering, or mathematics (STEM) degree program. This process was created and developed to find scholarship awardees for a 2016 National Science Foundation S-STEM grant, #1644143 *Rising Scholars: Web of Support Used as an Indicator of Success in Engineering*.

In this paper, the Background section will discuss the history of access to higher education since the Morrill Act. It will also cover how current admission processes and federal financial aid practices are failing the low-SES and underrepresented minority (URM) applicants who aspire to become engineers. A general outline of the program philosophy and collegiate pathway for the students will be provided. The Design of the Selection Process section will contain sub-sections for Goals and for the Methodology of Selection Process Design. It will discuss how factors reviewed in the Background were utilized, along with a prior study on collegiate success of URM students at Purdue, to build a method of selecting the NSF S-STEM scholarship awardees. A test to determine whether these students selected by the Rising Scholars methodology are truly different from those admitted directly into engineering will be proposed. The Results and Discussion section will contain an Execution subsection about utilizing the selection methodology and an Outcome subsection about the selected students and their group make-up. Details regarding the process of selecting 21 students to receive a renewable scholarship of up to $6,500 annually for four years and to take part in the research program of the grant will be provided, along with a comparison of demographic and population results from the overall selection process. Finally, a Conclusions and Next Steps section will discuss the preliminary outcomes for the selection methodology, the lessons learned in the system development and utilization of the methodology, and the next steps for the overall Rising Scholars research program.

2 Abbreviations

ABE – Agricultural & Biological Engineering
ACT – American College Testing
AP – Advanced Placement
CODO – change of degree objective
CoE – College of Engineering
COVID – coronavirus disease 2019
CR – critical reading test component
EABC – Engineering Academic Boot Camp
ESP – Exploratory Studies Program
FAFSA – Free Application for Federal Student Aid
EFC – estimated family contribution
Fnn – fall semester of nn
FYE – First Year Engineering
FTFT – first time, full-time
GPA – grade point average
IRB – Institutional Research Board
LSAMP – Louis Stokes Alliance for Minority Participation
M – math test component
MEP – Minority Engineering Program
MITE – Multiethnic Introduction To Engineering
NSF – National Science Foundation
SAT – Scholastic Aptitude Test
SES – socio-economic status
SPSS® – Statistical Package for the Social Sciences, an IBM® software package
Spnn – spring semester of nn
STEM – science, technology, engineering, and mathematics
S-STEM – Scholarships in Science, Technology, Engineering, and Mathematics
RS – Rising Scholars
URM – underrepresented minority
W – written composition test component
WWII – World War II

3 Literature review

The overall Rising Scholar Program at Purdue University was designed to find and recruit appropriate students that demonstrated an understanding of the importance of support networks to academic success. The program taught the students to nurture their existing adult support networks and enhance them with new collegiate mentors, thereby potentially offsetting some of the documented barriers facing low socio-economic status (SES) students in higher education. This Literature Review section will provide background on the challenges of low SES students in higher education and provide an outline of the path chosen for Rising Scholars students in the Purdue University program assisting them.

3.1 Background on the dilemma of low socio-economic students

A liberal view of who should attend colleges and universities in the United States culminated in the Morrill Act of 1862, establishing land-grant institutions. This was furthered in 1890 by ensuring that race was not an obstacle for admission at these schools. The key charge within these federal acts was that the land-grant universities were to be "accessible to all". However, the road to obtaining universally accessible higher education has been fraught with many difficulties. A review of Black students in higher education, and specifically in engineering, aptly illustrates this point. In pre-WWII America, approximately 90.0% of Black Americans lived in poverty. Only 1.6% of Blacks earned a college degree, and they made up only 0.5% of engineers in the workforce. Improvements were made post-WWII, both with regard to poverty rates (55.0%) and in the numbers of college degrees (5.4%), but the percentage of Black engineers remained at 0.5%. The creation of holistic admissions processes and the reform of government financial aid access initiated in the late 1970s began to slowly make a difference in the admission of Black applicants into engineering, and the number of Black graduates grew modestly, eventually tripling between 1960 and 1990, as Black engineers in the work force grew from 0.5% to 1.5% [3].

Higher education provides leverage for individuals attempting to move-out of poverty, but college degrees are still difficult for the children of low-income families to achieve [12]. It has been shown that high-income families have a 50% chance of their children earning a bachelor's degree by the age of 25, but low-income families have only a 10% probability of obtaining the same degree [15]. This is unfortunate, since education has a strong influence in improving one's economic standing. The lowest quintile of the population showed significant economic growth with a college degree. In the lowest strata, 45% of adults remained in poverty without a college degree, yet only 16% remained when a college degree was earned [16]. Clearly, higher education is an effective means to elevate individuals above poverty, but for many, the path is arcane and obscure. A College Board official has admitted, "The least bright rich kids have as much chance of going to college as the smartest poor kids [17]."

The United States holds to the idea of a meritocracy, where all persons should be able to reach as far as their individual merit can take them. The goal of US land-grant universities should therefore be to choose the most diverse and worthy student body available to them. However, many of these 'accessible to all' institutions are now classified as 'Tier 1 Research, Highly Competitive' by the NSF, making them very selective in their admissions. These top-tiered schools are evaluated and rated by having their admitted students in the top 35% of their high school class, with GPAs of 3.0 or better, having a SAT score of greater than or equal to 1240 or an ACT score of 27 or greater, and maintaining their school acceptance rate of less than 50% of applicants [17]. With far more applicants than available slots, and with states supplying significantly less of these institutions' budgets than in the past, the land grant universities now place great value on building classes of students who can pay full tuition, have superior talents that are aided by private lessons and camps, and are geographically diverse in origin [18]. The geographical diversity objective translates into more out-of-state and international students, who are billed using progressive fee structures, which add tuition surcharges for out-of-state and international status. Table 1 presents data showing how the number of international and non-residential URM students at Purdue University has increased from the early 1990s until 2019. This preference for tuition-upcharge students reduces the chance for low-SES students to be admitted into the incoming classes, since they tend to choose in-state schools that are less expensive for them to attend. This is particularly true within the highly desired STEM majors. Attendance at top-tiered schools also provides distinct advantages for their students. These include a greater chance of graduating, a better chance of attending graduate school, and a wage premium on entering the labor market [17].

Table 1. Comparison of three decades of underrepresented minority and international students at Purdue University, beginning in engineering with average cohort size

	1991–1995 Avg	**2001–2005 Avg**	**2011–2015 Avg**	**2019**
URM	7.1%	4.9%	7.1%	9.8%
Resident	3.6%	2.2%	2.2%	3.3%
Non-Resident	3.5%	2.7%	4.9%	6.5%
International	2.7%	9.8%	18.6%	16.0%
Avg. Cohort Size	**1625**	**1600**	**1812**	**2312**

STEM majors are generally considered as being more academically rigorous than non-STEM undergraduate majors, and STEM colleges have long recognized their problem with historically low graduation rates, when compared with liberal arts institutions. This encourages admissions offices to select the applicants whom they think will have the best chance of graduating. Table 2 shows the results of the National Education Longitudinal Study of 1988, which followed sophomores in high school from that year, with four follow-up checks through 2000. There is a 14% drop in graduation between the lowest and highest economic status quartile's 6-year graduation rate within a Tier 1 institution, but these data also show that even though the 6-year graduation rate for the first quartile of SES students is lower than the fourth quartile, these low SES students still graduate at the highest rate by attending Tier 1 institutions [17].

Table 2. Comparison of collegiate 6-year graduation rates (percentage) by a student's SES-quartile and college selectivity index [17]

	SES Quartiles				
	First (Low)	**Second**	**Third**	**Fourth (High)**	**All**
Tier 1	76	85	80	90	86
Tier 2	61	63	71	79	71
Tier 3	60	58	59	66	61
Tier 4	40	63	55	58	54
All	55	63	63	73	65

Source: Kahlenberg analysis of the National Education Longitudinal Study of 1988, National Center for Education Statistics, Washington, D.C., 1988 [17].

Low-SES students have a much higher chance of being their family's first generation in college and having underrepresented minority status. This is fairly apparent when considering the overall poverty rate was 11.8% for the general population in 2018, but it was very dependent on ethnicity, with 23.7% of the Native American population, 20.8% of the African American population, and 17.6% of the Hispanic population falling below the poverty line. This can be compared against only 8.1% of the White population living in poverty [19]. This results in many of the low-SES quartile students having three strong risk factors against collegiate graduation: a high need for financial aid, first generation student status, and belonging to an under-represented minority ethnic group.

These students can face a variety of challenges including: a lack of support from their families in getting into college; not knowing what to expect from the overall higher education experience; feelings of not belonging in the classroom and the social community; difficulties in understanding the financial aid process; and guilt at leaving their families behind [18] [20]. In general, the absence of connection to the higher education process within an individual's adult contacts makes it harder for them to excel at Tier 1 universities, even if they do make it onto campus, yet in spite of this, some students managed to thrive. This imbalance in outcome pushed the authors to initially explore the following practical question: what are the differences between the students in this group who graduate and those who do not? The simple answer would be the increased stress associated with traditional academic learning. The American College Health Association, which performs nation-wide studies of college students' overall health has reported that even before COVID effects, a little over 65% of college students had felt overwhelming anxiety sometime within the last 12 months and over 25% felt that this anxiety affected their academic performance [21]. While it has been shown that some stress or anxiety can increase the desire to learn, high stress will decrease performance [22]. These studies show the many ways that traditional, regimented learning can add stress to students' lives, and the youth of low socio-economic status already have a higher base loading of stress from their economic background. They worry about their family's ability to meet basic needs. These factors correlate to lowered academic motivation and performance [23] [24]. So for many, the additional burden of seeking a degree in higher education makes the total stress load overwhelming without sufficient support and coping mechanisms. The National Scientific Council on the Developing Child concluded that no matter what factors caused the stress, "the single most common finding is that children who end-up doing well have at least one stable and committed relationship with a supportive parent, caregiver, or other adult" [25].

Another researcher, Mr. Derek Peterson, studied issues of perseverance in Alaska Native adolescents, during a time that this demographic group had the highest suicide rate in the United States. He rigorously researched how students who thrived were different from those who did not. Peterson has worked in Alaska since the early 1990s and was the Director of Child/Youth Advocacy for the Association of Alaska School Boards between 1995 and 2004. Mr. Peterson's predictive assessment methodology was based on his 'Rule of Five Web of Support' and determined that more than any other predictor, students with a foundation of five people who can actively discuss the student's academic progress and provide encouragement to them to do well in school, will do well in school. Mr. Peterson stated that while one person works well, if there were five adults in the child's life who could ask and expect a truthful answer about how the student was doing academically, then this child would likely thrive [26]. This methodology has its origins in Benson's Developmental Assets model, which was built on 20 external and 20 internal assets which helped ground youth and prevent risky behavior [27] [28]. Peterson's system was originally used to improve student achievement within Native Alaskan elementary and secondary school districts with high dropout rates, but he has since implemented it in K-12 settings with positive effects throughout the United States, Canada, Europe, and Africa, under a variety of circumstances [29]. The RS program chose to incorporate several of Mr. Peterson's ideas and strategies into this university-level program, as his concepts seemed very reasonable and practical, cause-and-effect driven, and measurable.

Clearly, supportive adults help provide students with resilience. Child development experts believe that how a person relates to stressful situations can be thought of as a teeter-totter between positive and negative outcomes. The person's natural pre-disposition can be thought of as the fulcrum [25]. Some people can naturally handle stress better than others. Two factors for youth that are noted to aid in counterbalancing external stresses are having stable, caring, and supporting adults in their lives, as specified in Peterson's Web of Support, and building a sense of mastery over their life's circumstances. Mastery over circumstances can be considered adaptability, which can be practiced at any age by setting goals, problem solving, and resisting impulsive behaviors. Some researchers believe that having supportive relationships and practicing these skills can be more important than the individual talents of grit, self-reliance, and strength of character [25]. This could explain why some students who have struggled through high school can learn successful stress coping strategies that others, whose classes came more easily, might never manage to master.

The Rising Scholar planning group developed a research program that built onto the Peterson Web of Support model and focused on teaching students how to find useful and effective mentors. **The primary research question in this long-term work is whether students from low-SES backgrounds, possessing lower incoming metrics, can still have success earning a STEM degree with the help of a web of supporting adult mentors.** The program was designed to have ample sources of professional adults who could strengthen the students' webs of support. To test whether the existence of a web of supporting adult mentors could be used to predict collegiate success, quantitative indicators of performance, retention, and graduation have been collected for the Purdue RS students, along with matched pair data for similar students in the Purdue College of Engineering (CoE) and the Exploratory Studies Program (ESP). A comparison between the Rising Scholar students with the two matched sets will initially be used to determine if the students within the various groups are truly different as defined by traditional college entry metrics, and after following their collegiate progress, to determine if the web of support aided in creating positive academic outcomes.

3.2 Outline and design of the overall Purdue Rising Scholars program

The 2016 NSF S-STEM RS program at Purdue was designed to study residential (in-state), low-SES, URM applicants to engineering who were admitted to the university, but not into engineering. The selection process for these "Rising Scholar" students was influenced by the experiences of Purdue Minority Engineering Program (MEP) assisting underrepresented students, who face similar barriers to entrance into CoE.

The lagging enrollment of residential underrepresented minority students relative to the general population is presented in Table 3, which shows the enrollment numbers for first time, full-time (FTFT) students into the Purdue CoE cohorts from Fall 2005 (F05) to Fall 2015 (F15). While the overall cadre of URM students had grown during that eleven-year period, the residential URM enrollment was reduced to half the non-residential number of students, following the peak enrollment of in-state residential URM students in 2010. The desire for higher institutional rankings has been detrimental to residential URM applicants, as many of the in-state students who had previously been admitted into engineering prior to 2010, were pushed into other majors. Common movements for these students were into the College of Science, the Polytechnic Institute, or ESP where general, non-major students explore various career options. Potential students for the RS program were being pushed in these directions under the current admissions system and matriculation processes at Purdue. The Rising Scholar program chose to collaborate with the ESP, since their students were expected to be working on admission into another college, and the program's entire process was designed to help students transition into majors after matriculation.

The movement of applicants with lower incoming metrics into the Exploratory Studies Program also created a large disparity between the financial need of students in the ESP compared with those in the CoE. As seen in Figure 1, for students during the 2012 to 2015 school years, there were twice the number of students needing 100% financial aid in the ESP as in the CoE, and this held true for URM students, as well as for the general population of students. These data align with various references in the literature showing that lower socio-economic status, URM students struggle financially to be able to attend their in-state land-grant institutions [18] [30] [31] [32]. The scholarship component of the Rising Scholars program clearly has applicability within this segment of the collegiate population, and the establishment of contacts within the university financial aid offices was deemed essential to the success of this program.

Table 3. Eleven years of enrollment of first time, full-time students into the College of Engineering at Purdue University (2005–2015)

Cohort Year	Residential			Non-Residential		
	African American	Hispanic/ Latino	Total URM*	African American	Hispanic/ Latino	Total URM*
2005	15	23	42	20	20	44
2006	17	15	34	23	30	59
2007	12	19	34	21	32	57
2008	22	11	41	10	21	33
2009	22	26	50	15	26	43
2010	21	30	62	16	37	64
2011	10	28	40	27	41	83
2012	9	19	34	16	43	71
2013	7	25	41	12	66	93
2014	14	22	42	19	66	89
2015	15	21	42	24	64	103

Note: *Native American/Indigenous & Multi-racial numbers included.

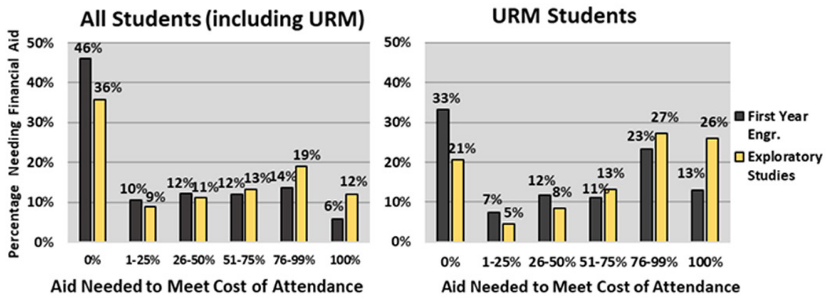

Fig. 1. Financial need compared between engineering and exploratory studies students at Purdue University (2012–2015)

Once on campus, URM students typically have a lower first year retention rate at the university, as is shown in Figure 2. No retention data seems to be available as to how low-SES students perform once on the Purdue campus, although some performance and retention data for low SES students in higher education has been published. In general, there is little information available specifically examining this demographic segment [17]. However, between F10 and F14, the local 5-year average for residential, URM student retention at Purdue was 91.0%. Using these numbers, the Rising Scholar administrators set a target for first-year retention within the university at 95.0% for the students within the program. Based on these numbers, the goal for moving into the CoE was established at 90.0%. The four- and six-year Purdue residential graduation rates are provided in Figure 3. For comparison, this study planned for the collection of the 4-year graduation rate of at least one of the RS cohorts. Based on overall university numbers, a longer-term goal for the RS group was a 6-year graduation rate of 80.0% within the CoE. Similar to retention data, if gender-based data for the low SES, URM demographic of students has been published, it does not appear to have been widely disseminated. The current level of women in the Purdue CoE is 26%. The research team set a balanced gender goal for the total RS cadre of a female-to-total ratio between 0.25 and 0.50.

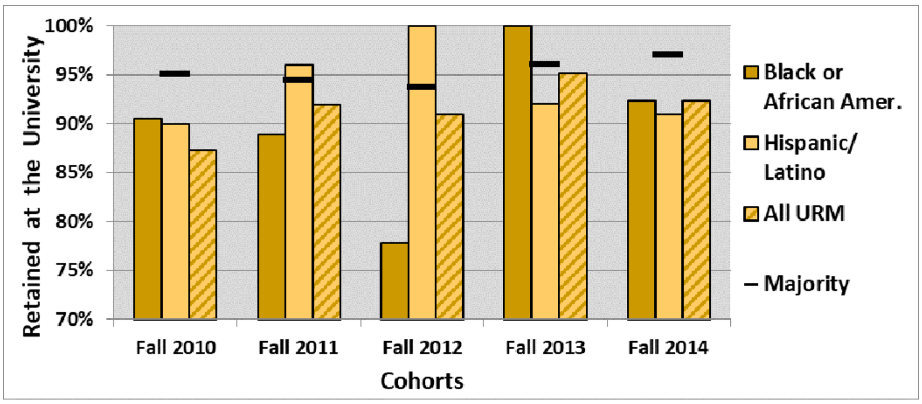

Fig. 2. First year retention for the fall 2010 to fall 2014 cohorts within the College of Engineering at Purdue University

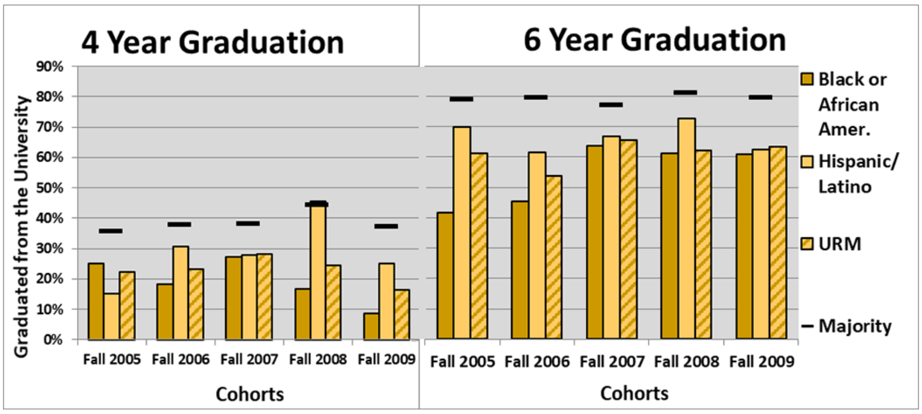

Fig. 3. The 4-year and 6-year graduation rates for residential students at Purdue University

The Rising Scholar students in the Purdue program were to be provided with a nurturing, high-touch environment that resembled many of the smaller engineering departments, like Agricultural & Biological Engineering (ABE), and the friendlier, more welcoming advocacy organizations, like the Purdue MEP. This student-friendly, community-driven approach to higher education has been proven effective for efficacy with other non-majority populations in engineering, such as women [33] and under-represented minorities [34] [35]. The program developers looked at existing advocacy programs and graduate satisfaction reports [36] for inspiration with regard to what to include within the program. RS students were to be provided with both modest financial support and opportunities to find on- and off-campus mentors through experiential activities. Communication exercises and camaraderie were emphasized within a proscribed 'best-path' through the university. This required sequence was defined as including:

- a pre-freshman collegiate STEM bridge program, known as Engineering Academic Boot Camp (EABC);
- a Louis Stokes Alliance for Minority Participation (LSAMP) research project with a professor in the student's desired major, following their freshman year;
- an individual or small group research project initiated by the Rising Scholar student, after their sophomore year; and
- an internship in industry, following their junior year.

Purdue University undertook an investigation of which campus-sponsored activities were critical in forming positive collegiate experiences that contributed to strong professional outcomes, and afterwards, these activities were encouraged for all college students to take advantage of to make the most of their college experience [36]. The RS program continued that initiative. Further, experience at Purdue ABE has shown that projects where students become vested, stimulate the best long-term connection with their overall profession [37]. Baldwin et al. have described the elements of experiential experience included within the RS program and how these elements were designed to make students more marketable upon graduation [38]. The advantages of properly structured project-based learning in a team-based environment [39] [40] [41], as well as the benefits conveyed by external experiential activities [42] [43] were included within the program's framework. Yearly seminars with the students and project administrators were planned to focus on building the Rising Scholars' support networks and to provide closure for the prior year's research or internship experiences. The reflective writing exercises in the program were designed to provide the students with the opportunity to understand and grow from their experiential experiences, as well as honing their technical writing skills [44] [45]. Additionally, the RS staff worked extremely hard to provide a nurturing culture to provide the students with the emotional support necessary for success in college by conducting social functions, maintaining continuous contact with the students, and providing generalized counsel [46]. These elements were incorporated to provide these students with opportunities to engage with STEM professionals and cultivate these university people into their personal support networks. Team work and connections were constantly emphasized as strong characteristics of successful professionals.

For the program to work properly, it was necessary to find the right students. Specifically, the program needed to recruit students that showed an understanding of the value of supportive adult mentor networks, as these were the individuals that were the most inclined to be able to excel under a system emphasizing support and connectivity. The selection portion of this long-term research program was designed to identify matriculating collegiate STEM students that were within the demographic segment of the population of interest. While the qualitative characteristics of successful engineering professionals and potential students have been described as including teamwork, leadership, problem-solving, creative thinking, analytical thought processes, and technical communication skills [47] [48] [49], quantitative metric values for predicting academic success in STEM fields are more difficult to determine. Numerous factors can affect the results and accuracy of the prediction. The RS research team was forced to evaluate specific quantitative measures and establish unique cut criteria for the program. Four sequential goals are reported here that were established to accomplish this Rising Scholars selection task:

1) The development of local applicant pool search capability to screen for admission and financial aid status;
2) The establishment of effective qualification minimums from which the pursuit of a higher education STEM degree is feasible;
3) The establishment of survey tools that quantify a student's adult supporter network; and
4) The establishment of survey tools to qualify the level of determination and persistence.

The tools for the completion of the first goal were available after the research team received access to the university's admissions program database. The successful design of a student screening process required that program goals two through four examined the following research-type questions:

a) Can a level of traditional incoming metrics be established to qualify as sufficient for the successful pursuit of a collegiate STEM degree?
b) Does the completion of AP STEM classes in secondary education establish a minimum qualifying characteristic for the successful pursuit of a collegiate STEM degree?
c) Do five actively involved adult mentors establish a minimum level of positive background support sufficient for the successful pursuit of a collegiate STEM degree?
d) Can determination and persistence displayed through a reflective exercise and focused interview establish a minimum qualifying characteristic for the successful pursuit of a collegiate STEM degree?

The criteria used to select the Rising Scholars was based on previous data from successful students who had moved into engineering from other majors and had earned a bachelor's degree in engineering. These criteria were measured and will be discussed, along with how well the selection process was able to meet these desired incoming metrics for the total group of Rising Scholars. The implementation of the process, along with its modifications through time, during the recruitment procedure will be presented. After the formation of the RS students and their matched pairs, a statistical analysis of whether there were significant differences between the groups was conducted to determine if the process had truly selected different students than the admissions methodology. Preliminary details about the performance of the selected RS students relative to their peers has been provided in Baldwin et al. [50].

4 Design of the selection process

The practical difficulties of selecting appropriate college students with the proper characteristics for a sound scientific research study are substantial. This is particularly true when working in a large university environment, subject to numerous changes outside of the experimenters' control. This section will initially examine the process designed to achieve the goals of the broader program within the existing Purdue University systems and provide details about the research team's decisions into the student selection process design.

4.1 The methodology of the selection process design

The first selection process goal required the development and utilization of staff skills within the university's enterprise management system and did not involve any analysis of design decisions. Within fairly constrained time limitations, a research team member with appropriate credentials was able to view and sort within the university's admissions database. This process was involved, but ultimately successful, as the researchers were able to screen accepted applicants for financial means, initial desired major, and matriculation status.

To crystalize thinking around the second objective, a 2016 local research study within the MEP was reviewed to determine what test metrics were sufficient for success in engineering and might predict graduation for low-SES and URM students, rather than the elevated values preferred by the admissions department. The data used for this five-year study were from the 2007–2011 admission years for the fall cohorts. Purdue University operates with an admission by college or program system, and all engineering students enter as a single cohort, independent of their preferred final professional school major. If the applicant is not admitted into their first choice for a major, then the individual may request to be considered for a second choice. The ESP is a general admission option that many Purdue applicants select when they are not given their first choice or are unsure of a desired major.

The 2016 MEP study looked at URM students who moved into the CoE's First Year Engineering (FYE) program by way of a Change of Degree Objective (CODO). There were 50 applicable students who had moved into the CoE from other majors inside this window, and 33 of them had mentioned being interested in engineering in their initial university application. There were 20 students that CODOed into engineering from the ESP, which was the largest group. Twelve students transferred-in from both the College of Science and the Polytechnic Institute, and there were six students from other non-STEM majors. Of these 50 successful 'CODO into Engineering' students, 40 ultimately graduated in engineering.

Table 4 presents the results of the graduation status of those students in the Spring of 2016 (Sp16). Looking at the six-year graduation of this group, there were 40 students who had graduated with a bachelor's degree in engineering and five who had changed majors a second time and graduated in a non-engineering major. This was an 80.0% graduation rate in engineering and a 95.0% graduation rate from the institution. This can be compared with students who entered engineering during those same five years. They had a graduation rate of 61.3% in engineering and 79.4% overall from the institution.

Table 4. Six-year graduation status of Purdue underrepresented minority students with change of degree objective into engineering from the 2007–11 fall cohorts

School	Graduated in Engr	Graduated from Non-Engr	Enrolled after Spring 2016	Voluntarily Withdrawn/Dropped	Total
Science	10	2	0	0	12
Polytechnic	10	1	1	0	12
Exploratory	14	2	1	3	20
Other	6	0	0	0	6
Overall	**40**	**5**	**2**	**3**	**50**

Figure 4 shows a graph of collegiate graduation GPA of the 40 CODO students who finished in engineering, against their SAT and high school GPA. All ACT test scores were converted to an SAT score using the ACT/SAT Concordance for 2005–2016 [51]. Students can take these tests multiple times, so the maximum score for each test type: Math (M), Critical Reading (CR), and Writing (W), was used in the evaluation, independent of the time taken. These results clearly show that URM students with far lower than the currently desired high school GPA and SAT scores for engineering admission demonstrate significant determination and can be successful in STEM majors. The overall incoming cohort of engineering students had a high school GPA average of 3.62 and 1272 for the SAT(CR/M). The CODO cohort who graduated in engineering had a high school GPA average of 3.16 and 1124 for SAT(CR/M). This is a drop of almost half a point in high school GPA and 150 for the SAT score. In fact, the lowest quartile of the group had ten students with an SAT of 1000 or less, and they averaged an engineering graduation GPA of 2.71. There were two extremely successful students, who from incoming metrics would not be expected to graduate with a college GPA above 3.0. One student earned an engineering graduate GPA of 3.20, while previously having a high school GPA of 2.94. Another had a SAT(CR/M) of 940 and obtained an engineering graduation GPA of 3.04. These two students have been circled on the graph. These results confirmed that other metrics besides test scores might be better predictors for graduation, especially for URM students.

The researchers felt that this study was useful in showing sufficient qualifications for seeking a degree in engineering and then continued by performing a deeper incoming metric space analysis. Partitioning Figure 4 with demarcation lines provides a potential bounding of the incoming metric space. A space defined by a high school GPA greater than 3.0 and a combined SAT score greater than 1000 holds roughly 60% of the successful students. A GPA greater than 2.6 and a SAT score of 900 contains 85%. Based upon this analysis, the RS research team established the former set of bounds as the desired traditional metrics, and the latter was defined as the sufficient set of traditional metrics.

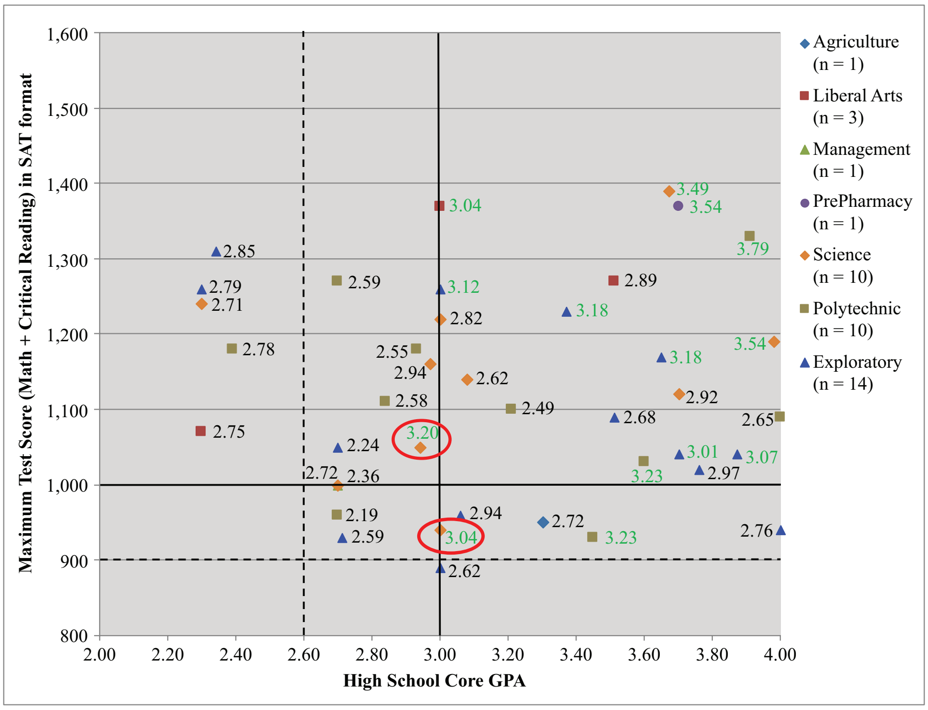

Fig. 4. Graduation GPAs of change of degree objective students earning a Bachelor of Science in Engineering at Purdue University plotted against high school core GPA and maximum equivalent test score: SAT(M/CR)

Notes: Numbers next to data points are Individual's P.U. Graduation GPA in engineering (Green: >3.00). Solid black lines show SAT(M/CR) and Core GPA values that bound 60% of graduates. Dashed black lines show SAT(M/CR) and Core GPA values that bound 85% of graduates.

4.2 The specification of the selection metrics

To determine other metrics that could be used to select Rising Scholars, the CODO group (n=40) was then compared against students who were directly admitted into engineering during the same time frame, but who didn't graduate (n=31). The incoming metrics that were compared between these two groups were:

- High School GPAs (Core, English, Math, Lab Science, and Foreign Language);
- Advanced Placement (AP) scores (Calculus AB, Calculus ABsubscore, Calculus BC, Chemistry, Physics B, Physics – electrical, Physics – mechanical, number of AP courses, Average AP score from all above tests, and total of all AP scores earned); and
- SAT maximum test scores with ACT scores converted to SAT scores (Math (M), Critical Reading (CR), Writing, M+CR, and Total).

The results of the Group Statistics for this data are shown in Table 5. Independent Samples Tests from SPSS® are shown in Table 6.

Table 5. Group statistics of High School Incoming Metrics compared between Change of Degree Objective (CODO) Graduates in the Purdue College of Engineering (CoE) against Purdue Engineering Direct-Admit students who didn't graduate in any major

High School Metric	Group Statistics			
	Group	N	Mean	Std. Dev.
Core GPA	CODO	28	3.17	0.53
	CoE Admit	31	3.37	0.35
English GPA	CODO	28	3.14	0.51
	CoE Admit	31	3.31	0.42
Math GPA	CODO	28	3.18	0.58
	CoE Admit	31	3.33	0.45
Lab Science GPA	CODO	28	3.15	0.56
	CoE Admit	31	3.33	0.42
Foreign Language GPA	CODO	28	3.24	0.67
	CoE Admit	29	3.34	0.50
CALC_AB	CODO	10	3.20	1.23
	CoE Admit	10	1.80	0.92
CALC_ABsubscore	CODO	3	4.00	1.00
	CoE Admit	0		
CALC_BC	CODO	3	3.67	1.15
	CoE Admit	0		
CHEM	CODO	3	3.00	1.00
	CoE Admit	3	1.67	1.15
PHYS_B	CODO	2	3.50	0.71
	CoE Admit	5	2.20	1.10

(Continued)

Table 5. Group statistics of High School Incoming Metrics compared between Change of Degree Objective (CODO) Graduates in the Purdue College of Engineering (CoE) against Purdue Engineering Direct-Admit students who didn't graduate in any major *(Continued)*

High School Metric	Group Statistics			
	Group	**N**	**Mean**	**Std. Dev.**
PHYS_elec	CODO	2	2.50	2.12
	CoE Admit	0		
PHYS_mech	CODO	3	3.67	0.58
	CoE Admit	0		
Number AP	CODO	28	0.93	1.36
	CoE Admit	31	0.58	0.77
Avg AP	CODO	12	3.17	1.09
	CoE Admit	13	2.00	0.91
Total AP Scores	CODO	12	7.25	5.12
	CoE Admit	13	2.62	1.33
SAT(M)	CODO	28	591	81.00
	CoE Admit	31	612	67.42
SAT(CR)	CODO	28	532	74.80
	CoE Admit	31	601	60.52
SAT(W)	CODO	28	510	71.08
	CoE Admit	31	574	63.75
SAT(M/CR)	CODO	28	1124	142.21
	CoE Admit	31	1213	110.62
SAT(Total)	CODO	28	1634	204.35
	CoE Admit	31	1787	160.28

Notes: Light gray denotes metrics which were statistically higher for the Direct-Admit students. Dark gray denotes metrics which were statistically higher for the CODO students.

Table 6. Statistical Tests of High School Incoming Metrics between Purdue Change of Degree Objectives graduates in engineering compared against Direct-Admit Engineers who didn't graduate with any degree

High School Metrics	Levene's Test for Equality of Variances*		t-Test for Equality of Means		
	F	Sig.	t	df	Sig. (1-tailed)
Core GPA	8.489	0.005	–1.712	45.816	0.047
English GPA	1.939	0.169	–1.401	57	0.083
Math GPA	3.478	0.067	–1.101	57	0.138
Lab Science GPA	2.942	0.092	–1.4	57	0.083
Foreign Language GPA	3.929	0.052	–0.595	55	0.277
CALC_AB	0.75	0.398	2.885	18	0.05
CHEM	0.308	0.609	1.512	4	0.102
PHYS_B	7.872	0.038	1.857	3.122	0.078
Number AP	5.765	0.02	1.195	41.596	0.119
Avg AP	0.499	0.487	2.928	23	0.004
Total AP Scores	11.025	0.003	3.044	12.36	0.005
Max_M	5.54	0.022	–1.067	52.765	0.146
Max_CR	0.734	0.395	–3.902	57	<.001
Max_W	1.019	0.317	–3.621	57	<.001
Max(M+CR)	4.131	0.047	–2.683	50.894	0.05
Max(Total)	2.419	0.125	–3.22	57	0.001

Notes: *Levene's Test for Equality of Variance (Sig > 0.05; Equal variances assumed). Light gray denotes metrics which were statistically higher for the Direct-Admit students. Dark gray denotes metrics which were statistically higher for the CODO students.

The Core GPA and Test Scores show that the Direct-Admit engineering students have a significantly higher mean than the CODO students. This is not surprising, since these are the metrics often used within the admissions process. A previous analysis showed that specific gateway values were used to provide an initial screening of incoming applicants for further analysis regarding admission into the CoE [52], and the process from that analysis was used for guidance in the present work. The AP courses were what became of interest to the group in devising other high school metrics to use for the Rising Scholar selection process. The Calculus AB test scores of the CODO group were significantly higher than the direct-admit engineers ($t(18)=2.885$; $p=0.05$). Four of the other six AP scores did not have any E student who took those tests, so a t-test could not be performed. The Chemistry and Physics-B test scores did not provide statistically significant differences. However, the metrics produced of average AP score among these seven tests ($t(23)=2.928$; $p=0.004$) and the total score obtained on the tests ($t(12.4)=3.044$; $p=0.005$) did create statistical significance with the CODO students having the higher means. With the higher number of tests taken, and higher average tests scores, it was felt that simply taking AP classes was a good indicator of the motivation for student success. These analyses were used to posit a requirement of having two AP courses between Calculus, Chemistry, and Physics.

The written application for the Rising Scholar Program was used to determine both the student's Web of Support and their grit and determination. In the application survey, students were allowed to include up to 25 people who they felt supported them in their lives and educational pursuits. The survey looked for positive traits and was administered to quantify the size and quality of the student's support network. The survey instrument was an Institutional Research Board (IRB)-approved, abbreviated version of Derek Peterson's 'Phactors of Support', which asked for people in the applicant's life that provided support to them [26]. The applicant listed the individual, how the individual was related to them, and what types of support the adult provided. Information about the quantity and quality of the student's adult mentor support network was parsed from this portion of the survey. As per Peterson's Rule of Five, it was desired to find applicants who had as close to five adults or more. The applicant then completed an essay about an experience that potentially illustrated the support of one of the adults listed in their network. A staff member examined the student submitted data on their support network. All successful applicants had five adult support mentors in their networks, following adjustment to account for previously unlisted members.

A quantitative measure of the student's determination was calculated using the Duckworth 12-question grit scale. Of particular interest were statements such as: I have overcome setbacks; I have achieved a goal that took years of work; and I finish whatever I begin [53]. The grit scale was created to examine six statements, each measuring perseverance and consistency of effort. Measurements used a 5-point Likert scale, and results were totaled and divided by 12. Duckworth notes that the grit scale is quite age and education dependent. In the results section, the data were provided that Ivy League undergraduates had an average scale of 3.46. The researchers felt that these potential Rising Scholar students would score high on the grit scale. While it was desired to have students who displayed grit at a superior level, a value of 3.30 was deemed sufficient for this program.

Students who finished the written application process were invited to campus with their parents for a "Rising Scholar Day on Campus" and an oral interview. These final on-campus interviews were conducted with a selection committee consisting of: one faculty member, one advocacy program director, and one professional staff member. The committee members were provided with a packet that included the applicant's high school transcript, essays, activities, Duckworth index, and the Rising Scholar written application. The research team developed an interview rubric to find how determined the applicant was toward completing their collegiate goals. This interview, created by an Engineering Education department faculty member, allowed the committee to evaluate:

- what things the student had done to determine that engineering was the right career choice for them;
- whether they had a realistic understanding about the difficulties in obtaining an engineering degree;
- that they had previously overcome doubters to achieve a goal; and
- if they could ask for help when they struggled.

The selection committee convened after the interviews to vote on the acceptability of each applicant. Members of the committee examined each student's packet and their interview notes to determine the strength of the candidate, to estimate their ability to utilize and grow their professional support network, and follow the best-path protocol through the institution.

The selection process methodology was designed to identify students that had an underlying understanding of the value of an adult mentor network. The standard high school metrics used by many admissions departments were determined to be overly restrictive for the low-SES students. An analysis was used to create other metric set-points that were sufficient to allow for success at the institution in STEM fields. These novel values were used to pre-screen for the Rising Scholar selection process. An additional evaluation of adult mentor support networks was added as a significant indicator used in the estimation of potential success. The next section will discuss the results of the three year implementation of this process.

5 Results and discussion: creating the rising scholar cohorts

The first year of the NSF S-STEM grant program was used to create the various surveys and processes to recruit and follow the Rising Scholars through their college program. The research materials that went through the extensive IRB process at Purdue included the recruitment emails, a recruitment survey, a series of recruitment questions to be used during an interview with the selection committee, an acceptance agreement identifying scholarship issues, a consent form for the research side of the program, a first-year fall survey, a continuing fall survey, and a spring survey. Once these materials were approved, work recruiting the potential students began in earnest during the second year of the grant. This section will discuss the execution of the designed selection process, how it was modified to accommodate university procedures as they were changed over time, the outcomes from the selection, and a statistical test to determine if the selected RS group was different from the admissions-selected engineering group.

5.1 Execution

The NSF S-STEM Rising Scholar research program was originally designed to have two years of recruitment, providing twenty qualified students. Unfortunately, it required three years to enlist enough students to follow the best-practice path created for the program through to graduation. Figure 5 shows the recruitment pathway graphically. The selection pre-screening process began with a professional staff member reviewing the applications of those students for the program's three traditional selection criteria: 1) having a core GPA of 3.00 or above; 2) having a SAT(CR/M) greater than or equal to 1000; and 3) having completed or enrolled in two of three AP courses in Chemistry, Calculus, or Physics. The values for these criteria were established using the 5-year graduation analysis described earlier. Applicants who were at or close to these criteria had their applications more thoroughly examined by the staff member to review any essays and transcripts provided in the Common Application. Students were split into groups of appropriate candidates and those that did not seem to be a good fit into the program. The appropriate candidates were contacted and asked to confirm their interest to be considered for the RS program by providing contact information in an online survey.

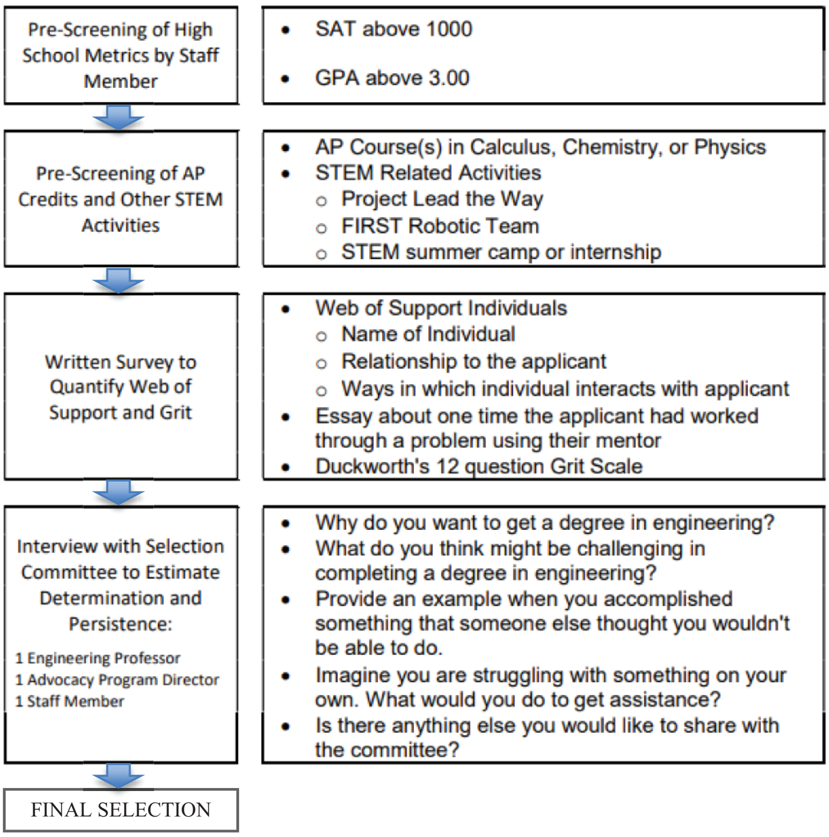

Fig. 5. Purdue Rising Scholar recruitment pathway for matriculation into the NSF S-STEM program

There were three years of recruitment for the Rising Scholars program. Unfortunately, during each year along the way, the admissions pathway into the institution changed in ways that affected the process of recruiting students into the program. For Fall 2017 (F17) beginners, the process began with checking students who had been denied engineering, but were offered another major (n=92). All student applications were reviewed to determine their high school metrics, involvement in work or social clubs, transcripts, written essays, recommendation letters, and whether they had requested a fee waiver or not. After FAFSA information was available, students not meeting the additional requirement of having a family need of at least $6,000, as determined by information from the Division of Financial Aid, were eliminated. There were 14 students who met all of the academic requirements, but did not meet the financial requirement or did not complete a FAFSA, and they were removed from consideration. Thirty-three (n=33) students meeting both the FAFSA and RS metrics were approached to consider joining the program. An introductory letter was sent via email, and when low interest was demonstrated, a telephone campaign was initiated to try to call these prospective applicants. Students were asked to complete the written survey showing their support networks, utilization of these networks, and their grit and determination (n=9). Two of those that showed interest became ineligible, once their late arrival FAFSA information disqualified them. The remaining seven RS applicants were invited to a "Day on Campus" event for a meeting with the selection committee. This interview process resulted in six students being given an offer to join the Rising Scholar program, which all six subsequently accepted. All of the students attended the Engineering Academic Boot Camp (EABC) offered during the summer by the MEP, prior to attending their freshman classes in the fall.

Since Purdue's admissions process went from a rolling admission to January and March decision dates for the F18 cohort, the procedure of creating the Rising Scholar candidate list was slightly altered during the second recruitment year. The administration's desire to increase student attendance and a change in FAFSA deadlines also affected the RS selection process. A professional staff member again rated engineering applicants that were classified as "Denied, Offer Alternate Major" for the RS program. Since six Rising Scholars were recruited in the first year, it was felt that with this experience, the team could easily recruit fourteen students for the second year. However, the desire for a larger class size at the university resulted in far more applicants being admitted into the CoE than in previous years. The Black or African American admission rate rose from 29% for the F17 engineering cohort to 41% for the F18 engineering cohort. Coupled with the larger application numbers, this resulted in 63 more African Americans students being admitted directly into engineering than the previous year. A smaller increase occurred with the Hispanic/Latino population, but this group consistently submitted more applications per year. Their acceptance rate went from 43% to 49%, which translated into 80 more Hispanic/Latino students being admitted for F18.

While these increases in URM acceptance were good for the individual applicants, these circumstances altered the dynamic for selecting RS students. At the national level, it was recommended for applicants to complete the FAFSA in October and use their parent's tax numbers from two years ago to receive the best chance at federal and state aid and to avoid a delay in financial aid data being available. The top choices for Rising Scholar candidates by the January admissions program decision date were selected, but since FAFSA decisions were due very close to that date, it was felt that receiving their Estimated Family Contribution (EFC) results would simplify the recruitment process by eliminating individuals who were not eligible for the program. Unfortunately, obtaining the EFC data took longer than expected, and the window that the students had to change their major for consideration was shorter than during the previous recruitment year. This combination of events created a very short timeframe of only two to three days for encouraging applicants to change their major to the ESP for the re-analysis of the admissions process.

Of the 33 applicants that were possible recruits for the RS program, eight students moved into the ESP. This number clearly precluded the possibility of recruiting 14 students for the second year. To increase the selection pool, the previous year's vetting process was retained, but additional candidates were considered who were accepted into the ESP as their first choice, but had listed engineering as their desired major, or had the high school metrics that qualified them for the RS program. There were an additional 37 students who met one of these two requirements. Of these students, three did not complete the FAFSA, six had an EFC that was too high, and twelve who listed engineering, but did not meet the RS requirements. These 16 more potential applicants and the original eight qualified students were contacted about the Rising Scholars program. Of the total 24 contacted students, twelve answered that they would like to learn more, and two replied that they were not interested. Nine students completed the written application and were invited to an interview with the selection committee. Eight of those students came to campus and were interviewed, and one did not attend. It was determined during the interview process that all of the students were qualified or would benefit from joining the program. These eight eventually accepted an offer to join the program. All of the accepted students enrolled in the EABC during the summer, prior to attending freshman classes later in the fall.

After one week, one student decided that she would not benefit from the EABC, so she left the RS program. However, there were two students in the EABC who had previously attended several MEP summer workshops and were admitted into the ESP, but were non-residents. After completing the written assignments and an interview, it was decided that they would be admitted into the RS program for the second year's cadre. This resulted in nine students joining the program for F18. This meant that at least five students would need to be recruited in a final cohort to meet the 20 projected participants, but potentially as many as seven students could join, since two of the first cohort had subsequently left the program for various reasons.

During the third recruiting year, the procedure of determining the final RS candidate list was changed again. Admissions continued to use the January and March decision dates, but applicants were encouraged up-front to make a second-choice major selection on the original application. This was done so that they could be moved directly into the second choice major, if they were qualified for the second choice and were not accepted into their first choice. This pre-empted the ability to phone many of the students who received the "Denied, Offered Alternate Major" decision and encourage them to choose ESP as their second choice. An email went-out from the MEP to all pipeline students who had attended prior summer programs. This correspondence encouraged students, if they weren't selected for engineering, to consider whether they would want to attend anyway and work toward entering the FYE program. If this was their desire, then they were encouraged to choose the ESP as their second choice major.

The RS recruitment pool during the third year began with 80 students who were not admitted into engineering or who had started in the ESP and had an interest in engineering. Thirty of those students did not have the high school performance metrics that were established as the program's criteria. Eight students never made a second major choice, and six moved into other majors besides ESP or were reconsidered and accepted into engineering. This resulted in 36 students who might be eligible for the RS program, if their financial need was high enough. Two of these students did not complete the FAFSA, and nine students had an EFC that was too high. This resulted in 25 residential students in the ESP being sent information about the RS program and a link to a Qualtrics® survey to show their interest in learning more. Five of the eight students who showed interest completed the written essay and were invited to a "Day on Campus". Ultimately, all of these students were given offers to join the RS program, and all five accepted. A non-residential student found the information about the RS program on the web, and she had previously visited an MEP recruiting day event. She had a WebX® interview with the committee later and was additionally accepted into the program. Three other students who attended the EABC as ESP students were also considered, but they neither met the necessary high school qualifications, nor did they submit a FAFSA. Figure 6 illustrates the process in which the recruitment procedure for the RS program was implemented and how many students were present at each step. Table 7 provides a synopsis of the three-year recruitment process.

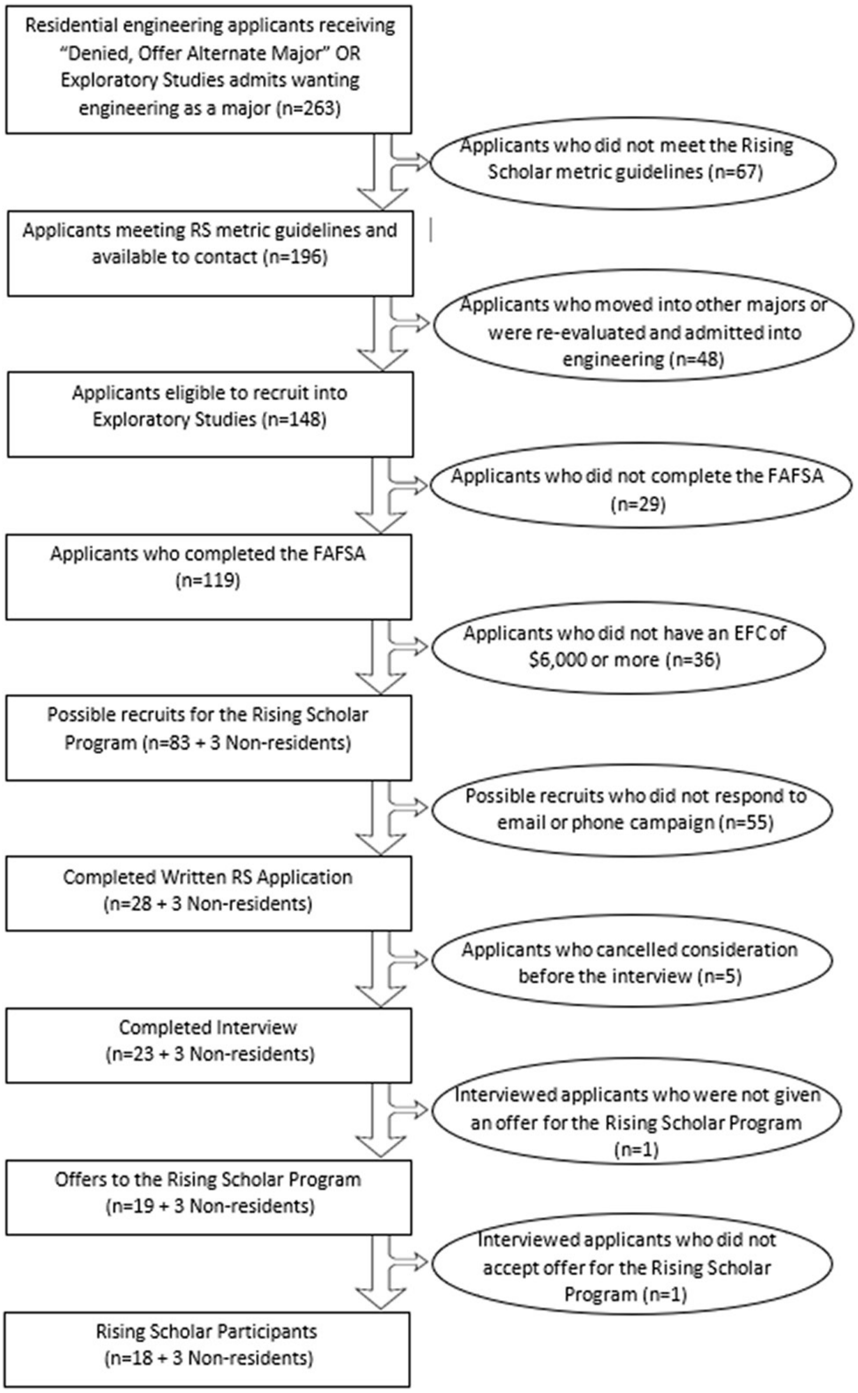

Fig. 6. Fall 2017–2019 recruitment process pathway details for the Purdue Rising Scholars NSF S-STEM program

Table 7. Summary chart of the yearly selection processes used to select qualified Rising Scholars at Purdue University, with the additional one or two students in F18 and F19 cohort denoting additional non-residential Rising Scholar applicants

	Fall 2017	Fall 2018	Fall 2019
Residential, US Citizen applicants receiving "Denied, Offer Alternate Major" OR Exploratory Studies admits wanting engineering	90	93	80
Met Rising Scholar metric requirements	64	82	50
Eligible to recruit to Exploratory Studies	44	68	36
Completed the FAFSA	35	50	34
Need of at least $6,000 met	30	28	25
Possible Recruits for Rising Scholars	30	28+2	25+1
Answered Email Interest	9	12+2	7+1
Took part in Interview	7	9+2	5+1
Invited to take part in the Rising Scholar program	6	8+2	5+1
Accepted Rising Scholar Offer	**6**	**7+2**	**5+1**

5.2 Outcomes

The selected 21 members of the three Rising Scholars program cohorts had the following demographic metrics:

- Gender: 9 – women and 12 – men;
- Residency: 18 – residentials and 3 – non-residentials;
- Ethnicity: 14 – Hispanic (1 with American Indian identity);
- Race: 3 – Black or African-American;
  4 – Two or more race (3 with Black and 1 with American Indian identity); and
- First generation: 11 students.

The overall group had a female-to-total ratio of 0.43, well within the original program goal. The in-state residency requirement was relaxed following a recommendation from the NSF contract monitor, but the overall group of RS students was still 86% residential. The RS group was 100% URM, and roughly half of the students had no direct family experience with higher education. In summary, these students as a group fit squarely inside the freshly defined low-SES Rising Scholar student demographic.

The desired traditional academic selection criteria for these RS students were a high school core GPA of at least a 3.0, with cumulative SAT scores above 1000. These criteria were met individually, but an additional analysis was performed to determine whether the RS group had statistically lower high school metrics than the FYE cohorts that were accepted during this three-year timeframe, and were therefore, truly different than the incoming FYE classes.

The statistical test for each metric analysis was:

$$H_0: X_{FYE} = X_{RS} \qquad H_1: X_{FYE} > X_{RS}$$

The averages and standard deviations of the two groups for GPAs and SAT Scores were calculated using SPSS® and are presented in Table 8. Table 9 presents the SPSS® statistical comparison information between the two groups. The RS average Core GPA of 3.56 and average SAT(CR/M) of 1191 were also above the targeted prescreening metrics, but it can be seen that an independent sample t-test resulted in all FYE metrics being statistically higher than the RS students' metrics.

Table 8. Group statistics of High School Incoming Metrics compared between Purdue College of Engineering Direct-Admit students against Rising Scholar students

High School Metric	Group Statistics			
	Group	**N**	**Mean**	**Std. Dev.**
Core GPA	CoE Admit	2043	3.79	0.20
	Rising Scholar	18	3.56	0.32
English GPA	CoE Admit	2040	3.76	0.26
	Rising Scholar	18	3.49	0.43
Math GPA	CoE Admit	2041	3.77	0.27
	Rising Scholar	18	3.49	0.43
Lab Science GPA	CoE Admit	2042	3.81	0.24
	Rising Scholar	18	3.56	0.38
MAX SAT(M)	CoE Admit	2097	714	51
	Rising Scholar	21	608	39
MAX SAT(CR)	CoE Admit	2097	696	50
	Rising Scholar	21	584	55
MAX SAT(M/CR)	CoE Admit	2097	1410	84
	Rising Scholar	21	1192	75

Note: Light gray denotes metrics which were statistically higher for the Direct-Admit engineering students.

Table 9. Statistical tests for GPA and SAT group equivalence between Purdue Rising Scholars and Engineering students from SPSS®

	Levene's Test for Equality of Variances*		t-Test for Equality of Means		
	F	**Sig.**	**t**	**df**	**Sig (1-tailed)**
Core GPA	11.095	0.001	3.088	17.12	0.004
English GPA	12.684	0.000	2.607	17.109	0.009
Math GPA	15.753	0.000	2.785	17.122	0.006
Lab GPA	14.265	0.000	2.668	17.116	0.008
SAT(M)	3.778	0.052	9.462	2116	0.000
SAT(CR)	0.051	0.822	10.244	2116	0.000
SAT(M/CR)	0.674	0.412	11.838	2116	0.000

Notes: *Levene's Test for Equality of Variance (Sig > 0.05; Equal variances assumed). Light gray denotes metrics which were statistically higher for the Direct-Admit engineering students.

Although the original selection criteria were reasonable, the initial guidelines were altered in some cases. Of the 21 students who were accepted into the RS program, 20 of them took Calculus as an AP course, either remotely through a four-year higher education institute or as a local community college student. There were five students who took AP Chemistry. Most of the students had taken a class in chemistry, during either their sophomore or junior year. Ten students had taken AP Physics, but there were several students who did not have Physics offered at their high school. Upon the recommendation of the NSF project monitor, the qualification criterion of having two of these three AP courses was relaxed to a single course, plus a significant alternative academic activity. This allowed a fuller cadre of potential students to be created. Other challenging and positive experiences were counted and considered equivalent to an AP course in demonstrating advanced academic potential. There is an empirical basis for this experience equivalence [54]. For our purposes, these alternatives could include taking the 'Project Lead-the-Way' progression of high school classes, having internships in engineering or medical facilities, being an active member of a FIRST Robotics team, or taking the 5-week pre-EABC Multiethnic Introduction To Engineering (MITE) summer workshop for rising high school seniors through the MEP. The MITE experience was an intensive curriculum designed to introduce the various majors of engineering, provide a long-term teambuilding design project, as well as daily classes for both mathematics and English SAT preparation, an introduction to calculus, and application essay writing. Two of the three non-residential RS applicants entered from this MEP program pathway. All of the students that entered the Rising Scholars program met the revised 'AP' goal of having an AP class plus an advanced academic activity.

The initial qualification written survey asked the students to complete the Duckworth 12-point grit scale questionnaire. The group interviewed had results spanning 3.42 to 4.58 with an average of 4.18. Most of these applicants were well-above the desired cut-off. Interestingly, the Rising Scholar applicants performed better on the measures of persistence than consistency. Persistency measures were 4.59 on the scale with a standard deviation of 0.29. However, consistency measures were lower at 3.77, and they had a wider standard deviation of 0.59.

The written survey for the applicants asked them about their support network and how they used it. The average number of anchors/mentors that were identified in this first survey was 6.2, which was above the Peterson's Circle of Five guideline to provide optimum support. Three students were given a provisional pass-forward in the screening process, because they had less than the requisite five adult mentors listed in their network. However, these students provided outstanding essays and were chosen to fill the cohort through an extremely positive interview, which indicated that their support network was likely broader than they had indicated. In all cases, it was felt that the program could help these students learn to build a broader professional support network and succeed professionally. All students were deemed to have met the criteria for an existing adult mentor support network upon revision of their support group numbers through the additional antidotal evidence supplied by the applicant.

At the end of the applicant review process, prospective applicants were finally invited to a "Day on Campus" discussion of the RS program, interviews with the final selection committee, attendance in a Purdue class with other students who had entered engineering through the ESP, and a campus tour. After the first year, the current RS students took the applicants to one of their classes and acted as tour guides. They provided the strongest testimonials on what they had learned from the program. With one exception, all students who made it to the final interview process, favorably impressed the selection committee. Their understanding of the power of persistence and their utilization of adult mentor support networks was so solid that, with this one exception, they were given an offer to join the RS program.

This completed the recruitment process for enrolling the Rising Scholars within the NSF grant program. Twenty-one students were initially provided with a scholarship, and their careers in higher education are currently being documented. In the first cohort, two students have left the Rising Scholar program. One student did not need the scholarship and was in a mandatory summer internship within her engineering curriculum, so she did not feel she could take advantage of the Rising Scholar summer programming. The other student changed into a non-STEM major. Eight of the nine second cohort are currently committed to a STEM degree, while one member is taking time away from campus due to COVID. Two members of the third cohort moved-out of STEM majors after their first year at Purdue, and they are no longer with the RS program. At present, there are sixteen students actively participating in the program. All 21 of the recruited students are being evaluated for retention throughout the course of the Rising Scholar program, and as of F21, 20 of 21 originally admitted Rising Scholars have graduated or are actively enrolled at Purdue University.

6 Conclusions and next steps

The RS program administrators were very satisfied with the overall selection process to obtain the group of students that became the Rising Scholars. There was an email campaign and call solicitation to introduce the program to applicants with a desired STEM career goal, but who were not admitted into engineering. A written survey was conducted, once a person had filled-out an interest survey. The final step was a "Day on Campus" program, which included an interview with the selection committee. The initial pre-screening high school criteria might have still been a bit too restrictive to obtain significant numbers of residential, Black or African American students that could move to the survey process, but the original criteria were eventually relaxed to select a full cohort of 21 students. The researchers readily acknowledge that the Duckworth Grit Scale used as one of the indicators has begun to have detractors [55] [56], but the persistence and consistency factors used in the metric appear to have performed well in the selection process in this program. Other grit or determination indicators could certainly be used in future research. Further study will continue to be performed determining what mixture of high school metrics, along with a strong web of support, might better predict success within the engineering and STEM fields for low-SES students.

Researchers at Purdue University received an NSF grant to investigate alternative experiences that low-SES students gain that could better predict success in collegiate STEM fields over standard incoming metrics. This program used these alternative criteria to select the Rising Scholar students:

- reducing SAT and high school GPA values below the traditional engineering entrance values;
- introducing a higher weighting of AP course enrollment in selection;
- establishing a metric for determination and grit; and
- pioneering ways to quantify and qualify the strength of a student's adult mentor support network.

These criteria were used to successfully identify and recruit 21 Rising Scholar students for a STEM major support program at Purdue University. For the long term evaluation of this program, the researchers will be examining:

- the retention rate of the students selected for the program and their matched pair cohorts;
- the entry rate of the Rising Scholar students and the Exploratory Studies students into the College of Engineering;
- the four and six year rates of graduation for Rising Scholar students and their matched pair cohorts from the College of Engineering, a STEM discipline, and Purdue University; and
- the effect, if any, of gender, race, and ethnicity upon the retention, GPA, and graduation rates of the Rising Scholar students and their matched pair cohorts.

A positive suggestion from this work would be that standard entrance applications should be modified to include the choice of an essay question that allows the applicant to discuss their support networks. Any program that works to provide scholarships to incoming low-SES students should also be well integrated with the existing institutional scholarship offices and Department of Financial Aid for efficient functioning and program execution. If residential and out-of-state individuals are to be chosen, then differential amounts might need to be considered for the scholarship portion of the program to equitize attendance. The original intent of the scholarship, as designed, was to reduce the financial stress on the low-SES students and to equitize their cost of attendance as residential students in state-supported institutions. The land-grant mission was shaped to create places of learning for local, non-elite background students to better their lives through education. The scholarship amount of $6,500 does not suddenly make a low-SES non-residential applicant completely able to afford that school, but it certainly helps their overall financial picture. In the end, three non-residential students expressed a desire to attend from their past experiences through MEP summer workshops that they were able to convince the selection committee that they would benefit from the Rising Scholar program. These students will be examined closely and compared against the residential students to see how well they are retained and graduated through the institution.

The RS students are required to move through a path of best practices in the university to aid in the acquisition of professional support network members, and the first step was the MEP Engineering Academic Boot Camp, designed to provide a smooth transition for underrepresented students into a globally competitive university environment. This program's premise is that if the university accepts these underrepresented minorities, then these students have what it takes to be successful at that university. The EABC program provides a student with a simulated first semester experience in the first year engineering courses, in a safe, consequence-free environment. The results of our RS students moving through this bridge program experience will be detailed next in a second paper in this series following the Rising Scholars through their collegiate careers.

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