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Value of Experiential Experiences for Diverse Student Populations Within Engineering Disciplines

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Dr. Carol S. Stwalley, PE joined the Minority Engineering Program team in the fall of 2007 as Recruitment and Retention Analyst. She earned her Bachelor of Science in Agriculture and Biological Engineering (ABE), MSABE, and PhD ABE from Purdue University. Carol has more than 14 years in diversity work with considerable background working with the Women in Engineering Programs at Purdue. In her current capacity as Recruitment and Retention Analyst for the Minority Engineering Program and the Purdue Office of Institutional Assessment, Dr. Stwalley collects, analyzes and manages data pertaining to the outreach, recruitment, retention and graduation of engineering students from historically underrepresented groups.

Dr. Robert Merton Stwalley III P.E., Purdue University at West Lafayette

Dr. Robert M. Stwalley III, P.E. joined the Agricultural & Biological Engineering department as a faculty member in the fall of 2013. He earned his Bachelor of Science in Agriculture and Biological Engineering (ABE) and his M.S.E. and Ph.D. from Mechanical Engineering at Purdue University. Dr. Stwalley is the former Director of Professional Practice at Purdue, has more than 20 years in STEM education, and has been a long-term advocate for improving equity in education. He is a long serving public school board member and President of the Indiana School Board Association. In his current capacity as an ABE professor, Dr. Stwalley works on precision livestock instrumentation to improve animal welfare and performance, increasing potable water access in the developing world through tube well utilization, and equity in access to higher education for low socio-economic status students. Dr. Stwalley developed the Rising Scholars program to help demonstrate that access and support are the most crucial elements of success in higher education for STEM majors.

Ms. Grace Lynn Baldwin

Grace Baldwin, joined the Rising Scholar NSF S-STEM program in the Summer of 2017 as a Graduate Research Assistant. She completed her Bachelor of Science degree at Purdue University in Agricultural and Biological Engineering (ABE) with a focus in Environment and Natural Resources Engineering. She has worked with the Rising Scholars' Program during the completion of her Master of Science in Agricultural and Biological Engineering and into her current Ph.D. program at Purdue University also in ABE. As part of the Rising Scholars' program, she has helped plan and organize the student recruitment events, align students with summer research experiences and faculty mentors, and conduct student interviews for program analysis and evaluation. Ms. Baldwin has actively contributed to the collection and analysis of data for the Rising Scholars program, as well as the dissemination of information about the progress of the program.

Ms. Virginia Lynn Booth-Womack, Purdue University at West Lafayette

Virginia received her B.S. in Industrial Engineering and a B.A. in Psychology while at Purdue University. She is currently the Director of Minority Engineering Programs in the College of Engineering. She assumed the position in 2004 after 18 years of manufacturing experience. Her last assignment was Lean Manufacturing Manager for the for the 3.7L and 4.7L Mack Engine facilities at Chrysler Corporation in Detroit, Michigan. Virginia has applied lean manufacturing concepts to identify and close the achievement gap between under-represented minority engineering students and the total engineering cohort. This was achieved focusing on first semester performance and first year retention through implementation of an aggressive transition program targeting first year engineering students from historically under-represented groups. She recently was called upon to serve as interim Executive Director for the National Society of Black Engineers from December 2013 through August 2014 during which time the organization experienced membership growth and strong metric focus towards goal attainment.

Sarah LaRose

Dr. Sarah E. LaRose joined the Department of Agricultural Sciences Education and Communication at Purdue University in the fall of 2018 as an Assistant Professor of Agricultural Education. She earned a Bachelor of Science in Animal Science and a Master of Arts in Curriculum and Instruction from the University of Connecticut, and her Ph.D. in Agricultural Education and Communication from the University of Florida. Dr. LaRose has over 13 years of experience in agricultural education in secondary and postsecondary settings. Since joining the faculty at Purdue, Dr. LaRose serves as a teacher educator, preparing future agricultural educators to meet the needs of a diverse array of learners in their classes. She teaches coursework in curriculum design, laboratory teaching practices, and teaching methods in agricultural education. Central to all of Dr. LaRose's work as an educator and a scholar is an effort to address inequities in agricultural education curriculum, program design, and recruitment practices.

Value of Experiential Experiences for Diverse Student Populations within Engineering Disciplines: A Work in Progress

Abstract

Traditional admissions processes at top institutions predominately utilize standardized test scores when comparing student applications. The equity of these high-stakes tests most severely affects students of low socioeconomic status (SES). The NSF-sponsored program, *Rising Scholars: Web of Support used as an Indicator of Success in Engineering*, was created to investigate whether alternative admission criteria could be used to identify low-SES applicants who would excel within STEM fields in higher education, even if they did not have the superior standardized testing metrics preferred by current admissions process. The quality of the student's support networks and their readiness for higher education as determined by an in-person interview with the selection committee were used as input data for a Web of Support characterization model to predict a student's likely collegiate success at the matriculation point. There were three cohorts with a total of 21 students chosen for the program during their entry to the university which included applicants of low-SES and under-represented minority status. A significant programmatic element for these students was their involvement in experiential activities through pre-existing programs in the institution. It was reasonably assumed that the Rising Scholars student population could be positively influenced toward long-term educational commitment through experiential activities providing realistic views of professional activity. The prescribed collegiate path for these students contained an experiential educational element for each summer between admission and graduation. A summer research project with a faculty-directed laboratory before the sophomore year and a self-directed research project prior to the junior year were used to build project management experience, along with a paid, external internship in a professional organization likely to hire within the student's major. Based upon the limited data collected so far, the researchers seem to have been conclusively demonstrated that a structured, 'high-touch' program with a heavy experiential component can successfully move low-SES students with STEM inclinations through a highly ranked institution. Counselling to reduce the anxiety surrounding the collegiate process for first generation students and some form of scholarship support to reduce the financial burden are both crucial underlying elements to this program's success, but the importance of hands-on, experiential activities that help the student visualize their professional career cannot be under-estimated.

I. Introduction

The purpose of land grant institutions of higher education, as defined under the Morrill Act, is to provide opportunities for the residents of their home states to achieve a collegiate education at a reasonable price and enhance the educated work force living within the state. Unfortunately, the decline in state support for these schools and the rising costs of operation have forced land grant schools to admit more out-of-state and international students that pay tuition upcharges for their incoming classes, at the expense of in-state, residential students. This is particularly problematic for low socioeconomic status (SES) students, because they tend to overwhelming select public land grant universities as their schools of choice for higher education [1]. Most of the popular majors offered at these institutions are in science, technology, engineering, and mathematics (STEM) fields, and those are especially competitive for admission. An additional burden on the low-SES students is that many of them are in the first generation of their family to attend college or are underrepresented minorities (URM). These students contend with issues that many affluent, majority individuals cannot comprehend [2].

An NSF S-STEM grant, *Rising Scholars: Web of Support used as an Indicator of Success in Engineering*, was developed at Purdue University to explore the connection between student support networks and success within collegiate STEM field majors. Low-SES applicants that were denied admission directly into engineering, but given admittance into the university, were recruited for the Rising Scholar (RS) Program. The quality of the student's support networks and their readiness for higher education as determined by an in-person interview with the selection committee were used as input data for a Web of Support characterization model to predict a student's likely collegiate success at the matriculation point. Continuing support was provided to the RS students by the creation of a nurturing and supportive 'high-touch' environment. The Gallup Index clearly demonstrated that having at least one collegiate faculty member take an interest in a student's development and success makes a positive difference in the student's view of their overall collegiate experience [3]. The student/professor climate of the Agricultural & Biological Engineering (ABE) was used as the goal for the overall relationship with the students, and this element of the program is detailed in [4]. For providing continuing data to the researchers and following a prescribed path through the institution designed to ensure interaction with professional contacts and potential support network members, the RS student was provided with an annual scholarship of $6,500. This value was chosen since it was the approximately the average between the top two residential merit awards through the university and covers 70% of residential tuition. The demographics of the 21 students chosen for the program are:

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.

These authors present a work-in-progress update for the overall program, including the improved retention and GPA data for the RS students in comparison to direct-admit engineering students and the exploratory studies students [5]. These students were chosen for similarity in incoming metrics, ethnicity, gender, and first semester course selection. A significant programmatic element for these students was their involvement in experiential activities through the pre-existing programs of the institution with hands-on involvement in professional working tasks. This paper will explore that connection.

II. Background of the Rising Scholars Program

Although many institutions claim to be utilizing holistic processes to evaluate applicants, the reality is that many times these measures heavily weigh the results of standardized testing [6]. These processes place many low-SES applicants at a significant disadvantage [7] [8]. Students fitting this profile and persisting through higher education to better themselves have become known collectively as 'Rising Scholars' [9] [10]. RS students have significant difficulties with access to STEM disciplines [11]. Unfortunately, these students may encounter many constraining life issues based upon a lack of family support, a disorientation within their new collegiate

community, an overall confusion about the financial aid process, and a guilt at seeing the world they are about to enter without the rest of their families [12] [13].

To combat these negative circumstances from affecting the psychological well-being of the RS student, the National Scientific Council on the Developing Child determined that at least a single sympathetic adult was needed to give encouragement and support [14]. The developers of the RS program sought to demonstrate the feasibility of a predictive success model and a professional development methodology based upon using quality support networks. Mr. Peterson has proposed a predictive methodology that indicates that if a student has five supportive adults in their lives, they are far more likely to succeed academically [15] [16]. The current NSF program incorporated an alternative success predictor, based on the students' adult support network, for admission of students into STEM programs. The Authors provide the details regarding the RS selection methodolgy for the program [17].

The RS Program was designed to be a 'high-touch' path 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 Minority Engineering Program. This program traces its history of 45 years to the early establishment of programs within the College of Engineering to increase the exposure of underrepresented minority students to the many opportunities available to them along the path of attaining their engineering degree. These types of approved activities have included events designed to foster camaraderie and provide participants with opportunities 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. These activities were primarily designed to help set the level of performance expectations for collegiate workloads. During the summer before their sophomore year, Rising Scholar students were enrolled in the Louis Stokes Alliance for Minority Participation (LSAMP) program to work in a partnering faculty member's laboratory assisting their graduate students and post-docs. These students provided their intended major and professors who had interesting research on their application to the program. The LSAMP office reached out to these 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 provided potential support network contacts and demonstrated the organization and flow of work within a modern research laboratory. The sophomore seminar concentrated on communication skills and career selection.

During the summer before their junior year, students typically conducted their own research project in a Multidisciplinary Engineering Research Fellowship (MERF). The MERF experience was crafted to resemble the 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 [18] [19]. The junior seminar shifted focus toward employability. RS students are to experience an internship prior to their senior year to gain professional time within the workplace and improve their employability metrics [20] [21]. 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 [22].

III. Nature of experiential experiences

Cooperative Education was founded in 1906 at the University of Cincinnati and is universally considered the first formal experiential education program [23]. Numerous other institutions followed suit over the course of the next several decades, and several good literature reviews on cooperative education are available [21] [24] [25]. Over the years, a number of activities that incorporate similar educational objectives have begun to be considered as experiential education, including internships, service learning, and study-abroad [26] [27] [28] [29]. These experiential experiences promote contextural knowledge and help students integrate traditional academic studies into the professional practice of their chosen discipline. Students who engage in professional practice opportunities have long been recognized by their instructors as more motivated, more likely to ask appropriate and relevant questions in class, and better able to make the connection between abstract concepts and the practice of their profession [30].

The benefits of professional practice in the undergraduate educational experience are numerous. Students that get to view and participate in activities typical of those within their profession during their collegiate years are retained in school at higher rates than those who do not get similar experiences [31]. More maturity, a greater independence of thought and action, and a well-developed sense of responsibility have all been noted in professional practice students relative to their non-participating peers [32]. Dressler & Keeling [33] suggest that a deeper analysis of the extent of student learning through professional practice includes: an increase in disciplined thinking; an improvement in learning through the taking of personal responsibility for the outcome; a knowing of how to learn complex material; an enhanced capability for problem solving; a deeper analytical thinking; and an increased commitment to their discipline. Students with professional practice backgrounds also exhibit improved employability traits compared to their colleagues, including: elevated work ethic, enhanced social development, improved project planning skills, and advanced interviewing skills [34]. Finally, it has been suggested that professional practice students develop a stronger ethical sense, a deeper awareness of who they are, and an improved understanding of their own self, over their peers without relevant professional work experience [35]. These positive factors associated with experiential experience are all elements that would potentially benefit RS students coming from low-SES backgrounds, as they complete their degrees and move into the professional world. The positive relationship between practical hands-on experience and career success was incorporated into the design of the RS program.

The benefits to the participating professional practice students in terms of entry-level starting salary, job title, and job responsibilities have been well-documented previously [36] [37] [38]. However, an enhanced benefit from having professional practice experiences seems to be shown for women and URM students, those individuals that most need additional assistance and equity in hiring decisions [39]. The positive effect may be coming from the intangible boost given by human resources personnel to students with work experience in their professional fields at the entry-level. Having the experiential experience on the resume appears to provide the additional consideration necessary for these candidates to move through the initial screening processes and be evaluated on their more traditional, tangible merits. This positive advantage should prove useful for the RS students upon their graduation with STEM degrees as they enter the professional work force.

IV. Experiential experiences provided to Rising Scholar students

The RS Program utilized the elements of experiential education that students have consistently found appealing: on-the-job training and earned responsibility [20]. A progression of experiential experiences for each of the RS students was designed to sequentially show working to perform a specific task within a small organization, running a self-directed project, and working professionally within a larger organization. The RS program staff used the mechanisms of the Purdue Louis Stokes Alliance for Minority Participation (LSAMP) program to establish summer research experiences for the RS students to work inside academic laboratories across the institution. The overall LSAMP program is supported by the Graduate School at Purdue University and is designed to increase URM enrollment through the doctoral level [40]. The LSAMP program contains mechanisms that find supportive faculty members with projects for summer experiences with URM undergraduates to engage them in productive activity. The goal of LSAMP for URM undergraduate students is to provide them with meaningful work under empathetic and supportive faculty.

Students are expected to work half time on productive research tasks for the summer. The LSAMP staff includes professional development workshops and social activities for all of the participants during the summer session. Students get training in critical thinking, present their work at an undergraduate poster session, complete a local service project as a cadre, and receive a stipend for their participation [40]. The RS students uniformly report that they both enjoyed and benefited from the LSAMP experience. Table 1 lists the general areas for the RS students participating in the LSAMP program at Purdue University. Of the eighteen projects, ABE sponsored five. Electrical & Computer Engineering (ECE), Industrial Engineering (IE), Material Science Engineering (MSE), and Mechanical Engineering (ME) had two students each. Chemical Engineering (ChE), Computer Graphics Technology (CGT), Earth, Atmospheric, and Planetary Sciences (EAPS), Information Technology (IT), and Nuclear Engineering (NE) each had one project. The diversity in student project topics is apparent, as well as the overall technical level of the work. The RS students were able to successfully integrate into a working laboratory, learn the existing processes and procedures to be able to safely and competently assist in the work, and then properly describe the activity and its importance.

The RS staff concentrates on a reflective write-up of the experiential experience during the following term in the manditory seminar course. Four of the Fall 17 cohort have completed their LSAMP project write-ups for publication in an undergraduate journal [41] [42] [43] [44]. One of the six member Fall 17 cohort dropped from the program due to incompatibilities with her major and the summer RS programming, prior to the LSAMP experience. A second member of the Fall 17 cohort changed degree objective into a non-STEM major during the following fall and did not complete the write-up portion of her RS commitement. One of the non-residential students in the Fall 2018 cohort has taken a leave-of-absense from the university to try to become an emancipated individual to obtain residential status. She plans to return in Spring 2022. Two students from the F19 cohort left the program to pursue non-STEM majors. The NSF S-STEM programs requires that the students remain in a STEM major to remain in the program and receive the scholarship. The program administrators have worked with students who have needed to work during non-summer terms. Examples include allowing a student who worked during the

seminar to zoom into the sessions. Another student was sent to work with the enginering scholarship office where he found the ability to cut his work hours by 50%.

Table 1 – Sponsoring Academic Department and Project Title for Purdue Rising Scholar Students Participating in the LSAMP Summer Experience (2017-2019).

Cohort Member	Department	Topic
F17.1	ABE	Hog Cooling Pad Experience
F17.2	ABE	Cooling Pad Controller Development
F17.3	IT	Students' Perception of Cyber Security
F17.4	NE	Data Mining to Prevent Cyber Attacks on Nuclear Reactors
F17.5	ABE	Cheap Yeast Infection Test Kit Development
F18.1	MSE	Hydrogen Embrittlement in Steels
F18.2	EAPS	Using $\Delta^{17}O$ Values of Nitrate to Estimate Precipitation Changes
F18.3	CGT	Finding Variances for Quality Control of Parts Manufacturing
F18.4	ABE	Bench Testing Hog Cooling Pads for Thermal Properties
F18.5	ME	Shock Pulse Absorption in Non-Newtonian Fluids
F18.6	MSE	Cross Linking a Polymer to Improve Strength
F18.7	ECE	Machine Learning and Neural Networks
F18.8	IE	Literature Review on Older Drivers and Their Self-Reported Abilities
F18.9	IE	Care for Rats with High-Thoracic Spinal Cord Injuries
F19.1	ABE	Water and Energy Analysis for Hog Calorimeter Testing of Cooling Pads
F19.2	ECE	Coronal Mass Ejections
F19.3	ME	Technological Innovations and Design Thinking for Policing and Social Justice
F19.4	CHE	*Needs to do this summer*

Continuing professional training for the RS students focused on project management skills. For their Multidisciplinary Engineering Research Fellowship (MERF) experiences, the students were expected to take ownership of a project and plan their own research effort to get a head-start in preparing for their own capstone experiences. The RS staff utilized the capstone teaching experience of the Principle Investigator to supervise the various self-directed student research experiences. These experiences received academic oversight from the ABE curiculum committee, and at the discretion of their home departments, the RS students were able to use the MERF class as a technical elective. Each RS student had a small budget to work with, was assigned technical mentors to interact with, and was responsible for engaging with university personnel to move their projects forward. The students were responsible for meeting their project objectives, keeping their work moving in a timely fashion, and determining whether their research objectives had been successfully achieved. The goal of this part of the program was to teach self-reliance and initiative within the framework of a technical project.

The RS students were expected to work half time on their MERF projects over the summer. Unfortunately, schedule delays and COVID upset planned timetables for the second round of MERF projects, and several second and third year RS participants have been forced to plan and execute their projects during the regular school term. However, this does not seem to have affected the quality of the experiences for the students. Table 2 presents the cooperating academic department and the title of the MERF projects undertaken by the RS students. Of the eleven projects, IE, and MSE were the sponsors of two each. ABE, CE, CGT, EAPS, ET, IT, & ME worked with RS students to complete one project each. Student write-ups were reviewed and improved during the fall seminar following the MERF experience. From the Fall 17 cohort one member has completed his MERF project write-up for publication [45]. Other members of the first and second cohorts are still editing their MERF documentation.

Table 2 – Sponsoring Academic Department and Project Title for Purdue Rising Scholar Students Participating in the MERF Summer Experience (2018-2019).

Cohort Member	Department	Topic
F17.1	CE	Concrete Strength *(changed topic from LSAMP to more align to major)*
F17.2	ME	*Needs to choose a topic*
F17.3	IT	AI in Cyber Security *(Continuation of LSAMP research)*
F17.4	ET	Weighted Jacket to Calm Anxiety *(Product development of individual interest)*
F18.1	MSE	Hydrogen Embrittlement in Steels *(Continuation of LSAMP research)*
F18.2	EAPS	Computer Learning Module about Geology *(Team project using both majors*
F18.3	CGT	Computer Learning Module about Geology *to create a learning module)*
F18.4	ABE	Ambient Room Conditions for Hog Calorimetry with Cooling Pads *(Continuation of LSAMP research)*
F18.5	ME	Shock Pulse Absorption in Non-Newtonian Fluids *(Continuation of LSAMP research)*
F18.6	MSE	Cross Linking a Polymer to Improve Strength *(Continuation of LSAMP research)*
F18.7	ECE	*Needs to choose a topic – On leave of absence*
F18.8	IE	Building a Technical Term Dictionary for Computer Learning *(New topic working with new professor)*
F18.9	IE	DaVinci Hardware Performance Analysis *(New topic working with new professor)*

The final experiential phase of the RS journey through higher education was the incorporation of a significant paid work experience for an organization with a defined mission. The RS staff is working with the Purdue Office of Professional Practice (OPP) and Center for Career Opportunities (CCO) to execute this piece of the program. The function of the OPP office is to facilitate undergraduate professional work experience through approved venues [46]. The importance of work experience within collegiate learning has been recognized for many decades [23]. Understanding the unique social culture of organizations first-hand is a valuable experience for most students, but it is especially likely to be beneficial for those of low-SES backgrounds. It may likewise be surmised that to be able to initially work within a professional environment in a

relatively consequence-free manner may dramatically help RS students with their long-term professional success. The CCO maintains a vast database for Purdue students to assist them in establishing entry-level professional employment, and it conducts several levels of interview process training for students [47]. The RS students are encouraged to take advantage of these services to help them equitably compete for professional positions. This portion of the RS program is now just beginning to be operational. COVID slowed and stalled many corporate internship programs, and at least one RS student had their experience delayed and converted into a virtual assignment. Only the Fall 17 cohort is far enough into their program to be able to report any data for this experience, and that information is presented in table 3. The write-up and editing processes for the RS students' experiential experiences are currently incomplete.

Table 3 –Academic Major and Corporate Sponsor for Purdue Rising Scholar Students Internship Experience (2019-2020).

Cohort Member	Department	Topic
F17.1	CE	*COVID Delayed*
F17.2	ME	John Deere, Inc.
F17.3	IT	*Needs to do an internship*
F17.4	ET	Southwestern Advantage Co.

V. Closure

The Rising Scholars Program was designed to utilize an alternative admission criterion that could identify low-SES applicants who could excel in higher education. It was hypothesized that these students, despite having unfavorable standardized testing metrics currently used in the generalized admissions process, could demonstrate that they could succeed in higher education by understanding the importance of support networks. The RS developers decided to use the best practice programs already existing within the university's catalog of experiential activities to provide experiential programs, which were deemed to provide the best leverage for the students transitioning into entry-level positions. In particular, work experience within the world of larger organizations was postulated to provide the most equitizing performance enhancement for URM participants. To this point, nearly all RS students within the three cohorts of the program have finished their LSAMP experience within a faculty member's laboratory and are completing the write-up of their experience. Many of the RS students are working on the MERF experiences currently, and the senior cohort is inside the internship phase of their program. COVID has significantly affected all collegiate schedules, and the RS students have felt this issue, just like other college students. The RS staff have adjusted program schedules to accommodate problems associated with the pandemic, which include changing the timing of research projects, changing the seminars to spring to allow the completion of projects, and being more flexible in the ability of students to meet original program timelines. Students zoomed into their usual mid-term interviews to discuss current semester successes and problems and next semester courses. The program directors always have an open-door policy which had to convert to scheduling an appointment to talk. These were changes that needed to be made to work around pandemic guidelines put in place by the university, but they seem to have thus far been able to maintain the vital experiential content of the RS program. Student impression data is not available yet, though

the one person who has been on work assignment contributed his job offer to being able to discuss his experience from the LSAMP research.

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