



Enhancing STEM Students' Success through Faculty-Mentored Undergraduate Research and Scholarship

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ABSTRACT

Engaging students in faculty-mentored undergraduate research projects have been documented as an indispensable element in retention and enhancing STEM (science, technology, engineering and mathematics) students' learning experiences. In this paper, we report the outcome of the mentoring program, financial support of students in terms of the monthly stipend and tuition, and involving undergraduate students in research activities under the supervision of faculty members. The exploratory research is aimed at reporting the experiences gained from the five years scholarship and faculty-mentored undergraduate research program and the outcomes of engaging the students in paid research activities, and the awards and recognitions received by the students at a minority-serving institution (MSI). The work attempts to measure the students' satisfaction and the contribution of the scholarship program with respect to the students' academic achievements, graduate school enrollment in STEM discipline, paid internship and co-op and job opportunities secured by the students. The results of the students' survey indicated that the scholarship and mentoring program positively impacted their success in securing summer internships and co-ops, admission to graduate schools, and employment opportunities. The results of the study will have a contribution to the existing body of literature in providing additional insight into the likely positive influence of scholarship funding allocated and provided to students by academic institutions, government agencies, and private organizations in enhancing the educational and professional success of undergraduate students.

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INTRODUCTION

The funding received from the Department of Homeland Security (DHS) through the Scientific Leadership Award (SLA) provided us the opportunities to involve several underrepresented-minority undergraduate STEM students majoring in engineering and physical sciences. The DHS-SLA project provided financial scholarships in the form of monthly stipends and in-state tuition payments for fall and spring semesters. Qualified undergraduate students were recruited and assigned to faculty mentors to work on research projects, primarily in their major discipline. The project also provided travel support to the participating students to attend professional conferences and present their research findings at local, regional, and national scientific conferences. Under the scholarship and mentoring program we initiated in 2015, annually, about fifteen underrepresented minority STEM students have been awarded scholarships and participated in research

projects under the direction of faculty mentors. In addition to the financial support, the scholarship program encouraged the students to spend more time attending classes, studying, and participating in other academic-related and professional activities both on and off-campus, such as involving in student chapters and professional networking events than seeking off-campus employment opportunities. This positively contributed to the students in maintaining a good GPA, which is one of the primary factors for other on- and off-campus scholarships, securing summer internships and co-ops, completing their undergraduate curriculum in less than five years, obtain employment opportunities and pursue graduate studies in STEM discipline. The financial support also served as one of the motivational factors for the students to spend more time in the labs and be an active participant in the research activities, collecting data, interpret experimental results and draw conclusions, attend conferences and present their research findings. The hands-on research experiences

and experimental techniques learned also make them outstanding candidates in their endeavor to pursue graduate studies and as STEM professionals.

This work aims to study the effects of the financial support provided to students in the form of a tuition scholarship and a monthly stipend, and the faculty-mentored undergraduate research activities on students' academic and professional successes. To accomplish this goal, the paper is organized as follows. The next section summarizes a review of literature closely related to the current study, followed by the methodological approach. Next, the results and discussions of the findings are presented. The last section of the paper provides concluding remarks on the key observations and findings of the study.

Review of literature

Involving undergraduate students in research projects have been documented as an essential element of STEM discipline in retention and enhancing students' learning experiences (Amaya et al., 2018; Linn et al., 2015). Studies found that, besides strengthening the traditional students' learning experiences and providing practical laboratory and research experiences during their undergraduate studies, the experiences gained are highly beneficial in developing their professional identity (Hunter et al., 2006). The students with undergraduate research experiences demonstrated better interest and motivation to advance professional careers in STEM-related fields and pursue graduate-level studies (Amaya et al., 2018; Daniels et al., 2016; Lopatto, 2007; Aikens et al., 2017; Barlow and Villarejo, 2004; Russell et al., 2007; Xu, 2018; McDevitt et al., 2020; Gilmore et al., 2015; Collins et al., 2017). Barlow and Villarejo (2004) studied the likelihood of minority undergraduate Biological Sciences majors involved in an educational enrichment program in improving the participants' interest in their persistence in earning an undergraduate degree and pursuing a graduate degree. The results indicate that involving underrepresented minority students in research and educational enrichment programs improves the student persistence in earning an undergraduate degree and encourages them to pursue graduate programs in STEM discipline (Barlow and Villarejo, 2004). There are also research findings suggesting the

positive outcome of undergraduate research and the hands-on experiences on the students' creativity and promising entrepreneurial role (Zhan et al., 2018). A 'Learning by Research' approach whereby the class lectures are supplemented with experimental research is reported to have a major influence on building sustained research interest, understanding of the core principles of the subject matter (Costa, 2000), motivates creative thinking, product development, and entrepreneurial mindset (Zhan et al., 2018). Undergraduate research also enhances students' self-confidence, communication skills, and competitiveness in the labor market and their persistence in the professional careers in their field of studies, increasing the number of underrepresented minorities in science, technology, and engineering workforce (Daniels et al., 2016; Lopatto, 2007). Involving undergraduate students in research projects also has a positive correlation with retention of underrepresented minority students in STEM discipline and the students' success in research related STEM carrier. It is also a motivating factor for the students to pursue graduate studies in STEM fields earning a graduate degree in STEM fields (Linn et al., 2015; Barlow and Villarejo, 2004; Plotkowski and Joseph, 2011; Hathaway et al., 2002; Hunter et al., 2006; Eagan et al., 2013; Seymour et al., 2004). Using a survey collected from participants, institutional data on student credit hour and GPA, and controlling the students' initial academic level with their SAT score (Fechheimer et al., 2011), analyzed the statistical correlation between extended undergraduate research class participation and their GPA. The findings indicate that students' engagement in the research was likely to earn a higher GPA, which promotes students' success and academic performance as measured by their GPA compared with the students who do not participate in undergraduate research. As a result of all these benefits, state and federal governmental agencies, private and non-profit organizations and professional societies have been vital in providing internship and co-op opportunities to students and allocate grant funding to support scholarship and mentoring programs for graduate and undergraduate students.

The scholarship and faculty-mentored undergraduate program discussed here is different

from the traditional Research Experience for Undergraduates (REUs), and a Course-Based Undergraduate Research Experiences (CUREs) offered as an integral part of a discipline-specific curriculum. In both cases, the students have the opportunities to be engaged in research activities during summer for REUs and a semester-long research exposure for CUREs. There is compelling evidence suggesting that the research experiences provided through these programs are beneficial to the students involved. However, there are also research findings suggesting that undergraduate research experiences designed to provide repeated and long-term research experiences are more useful to students than programs providing short-term research experiences to undergraduate students (Thiry et al., 2012; Seeling and Choudhary, 2016; Lopatto, 2009; Hensel, 2012). In this regard, since our program was established with five-years sustainable funding from the Department of Homeland Security, we were able to provide long-term (more than a year) financial support and faculty-mentored research experiences for underrepresented minority undergraduate STEM students at MSI. The long-term and repeated research opportunities enabled the participants to have sufficient time to understand the research project, collect experimental data, analyze the results, and draw conclusions.

■ METHODOLOGY

The scholarship and mentoring program was initiated in 2015 and had been involving undergraduate STEM students every year for the past five years. The program leveraged the institutional resources within the College of Engineering and Physical Sciences, including the research labs and voluntary intellectual contributions of faculty researchers. Figure 1 shows the undergraduate students' academic major participated in the 2018/19 and 2019/20 academic years. As shown in the figure, the students' major and the scholarship awarded students encompass a wide range of STEM disciplines, including Physics, Chemistry, Construction, Mechanical Engineering, and Electrical Engineering. All the students recruited and mentored under this project have been all underrepresented minorities, with about 75 percent and 64 percent being female students in the 2018/19

and 2019/20 academic years, respectively. Overall, the results of the survey suggested that the female student participants were highly satisfied as compared with the male students mentored under the program. Based on the two academic years' aggregate response, the female students who 'strongly agreed' and 'agreed' with all the survey questionnaires distributed were about 53 and 64 percent, respectively. In general, except during the midterm and final exam weeks, the mentees were required to participate in the research activities in the lab and interact with the faculty mentor for about one to two days a week. The weekly meetings and interactions of the undergraduate students with faculty researchers facilitate timely guidance and encouragement, which improves students' success (Aikens et al., 2017). For underrepresented minority students, faculty-mentored undergraduate research is a highly significant predictor of students' learning outcomes, including knowledge and skills gained, GPA of students, improved faculty-student interactions, and the overall students' satisfaction (Collins et al., 2017; Eagan et al., 2013). The weekly meetings with the research mentors, the end of semester seminar series presentations by all the mentees, the institutional annual STEM day poster presentations, attendances and presentations at local, regional and national conferences, and the refereed and conference articles fostering undergraduate students are also used as assessment matrices measuring the success of the program. The students' benefit in terms of scholarly productivity is also measured by including a questionnaire relevant to the number of the poster or oral presentations in local, regional, or national conferences, and the participation of the students' in scientific literature review and writing refereed journal articles and conference proceedings.

To understand the level of significance of the faculty-mentored undergraduate research and scholarship program, the students' satisfaction and perceptions of the research experiences, the awards and recognitions received, the conferences attended and papers presented and research articles published as a co-author, a survey with five levels Likert scale (strongly agree, agree, neither agree nor disagree (neutral), disagree and strongly disagree) have been developed and distributed at the end of each academic

years. Besides, the students have been required to submit a summary report listing the conferences attended; the summer internships participated, a list of articles they co-authored, and other significant accomplishments achieved within the academic year and the summer semesters. The results of the students' survey are summarized in Figure 2.

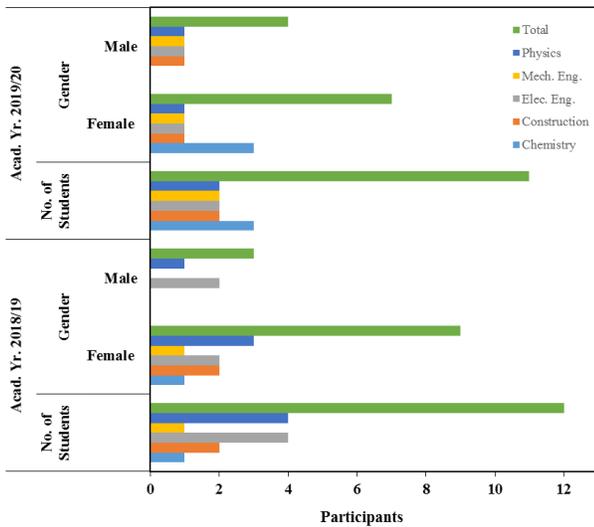


Figure 1. Participants' academic major and gender participated in the mentoring and scholarship activities in 2018/19 and 2019/20 academic years.

RESULTS AND DISCUSSION

The scholarship and the undergraduate research program implemented at Alabama Agricultural and Mechanical University provided a research and networking platform for a diverse body of STEM undergraduate students among themselves and with the participating faculty researchers. The program supported the scholarship recipients as monthly stipends and full in-state tuitions. As reported earlier (Barlow and Villarejo, 2004), minority students receiving scholarships and grants are more likely to persist in their study and earn their undergraduate diploma than students of the same background taking student loans. The scholarship and mentoring program offered practical research experiences to the scholarship recipients in the broad areas of materials characterization including Fourier transform infrared (FTIR) and Raman spectroscopy of building materials,

adulterants in food including olive oil, detection and identification of nitrates and other chemicals, fabrication and characterization of nanocomposite films, fabrication and characterization of thin-film thermoelectric devices, carbon nano-tube-based nano-electronics devices and integrated circuits, functional nanomaterials for energy harvesting applications, and optical characterization of crystals. For instance, in addition to the spectral analysis of materials, the students used FTIR and Raman systems to monitor the rate of hydration of cement mortar, and study the effect of thermal annealing on thermoelectric multilayer films. The results of the research findings have produced several presentations by the undergraduate students and co-authorship of scholarly articles, including refereed journal articles and conference proceedings. We believe that the scholarship, the research experiences provided, and the scholarly products enhanced the students' resume and their competence in the professional world. It is documented that continuing-generation and students from high-income families more likely to publish research articles during their undergraduate study than first-generation and students with low-income family backgrounds (Grineski et al., 2018). Our scholarship program has its share of contribution in closing such disparities and enhancing socially disadvantaged minority undergraduate STEM students' co-authorship of research articles and diversity in STEM discipline and workforce.

The mentee participated in the undergraduate research activities under the mentorship of faculty researchers presented their research findings and attended local, regional and national scientific conferences including the annual meetings of the Alabama Academy of Sciences (AAS), the annual Emerging Researchers National (ERN) Conference in STEM sponsored by the American Association for the Advancement of Science (AAAS) and the National Science Foundation (NSF) in Washington, D.C., the National Society of Black Engineers (NSBE), the annual National Society of Black Physics (NSBP), the National Women of Color STEM Conference, the BAYA Black Engineer of the Year Award (BEYA) STEM conferences, and other local and regional conferences. As these conferences foster networking opportunities, career fair events organized for both graduate and

undergraduate students, the attendee considered attending the conferences as valuable. Some of the conferences also served as venues for the students to build long-lasting networking opportunities with STEM carrier coaches and mentors for minority students.

As part of the objectives of the scholarship, the participating students have been encouraged to secure paid summer internships and co-ops. In this regard, the faculty mentors assisted the mentees in connecting them with paid summer internship programs. Some of the agencies and programs the students participated in summer internship programs include the U.S. Department of Energy's National Labs, Science Undergraduate Laboratory Internships (SULI) program, the U.S. Department of Defense (DOE) labs, NASA, Northrop Grumman Corporation, Apple, and the NSF-REU programs at universities across the nation. Some of the summer interns were able to get a fulltime job offer from the federal government agencies and companies they interned with.

As can be seen in Figure 2, more than 90 percent of the students agree/strongly agree that the scholarship and mentoring program provided them valuable research experiences. A similar response is obtained that the program increased the students' research interest in science and engineering. In both categories of the questionnaires, only 9 percent of the respondents neither agree nor disagree on the projects' contribution to the research experience and interest in science and engineering discipline. Regarding the projects' contribution to the summer internship opportunities secured by the mentee, again, more than 90 percent of the students in 2018/19 agreed that being a recipient of the scholarship contributed to the summer internship they secured. In the 2019/20 academic year, about 73 percent of the scholarship recipients indicated that the mentorship program they participated in positively contributed to the summer internship they had in summer 2019. The remaining 27 percent of the survey respondents neither agree nor disagree. A similar response is obtained for the program's contribution to the employment opportunities, except that about 8 percent of the responses in 2019/20 disagree that the scholarship program contributed to any job

opportunities. In their annual reports, the students confirmed that their internship and co-op applications were motivated by their participation in undergraduate research projects early on in their freshman and sophomore years, which ultimately shaped their search for summer internships and co-op programs, which later opened up opportunities for a full-time employment position. Based on the survey responses collected, the undergraduate paid-research and mentoring program implemented is successful in engaging the students and providing mentoring activities, which assisted the participating students in realizing their pursuit of academic and professional goals and success in the STEM career.

In terms of encouraging students to pursue graduate education, about 58 percent and 55 percent of the respondents in 2018/19 and 2019/20, respectively, agree/strongly agree that being part of the project encouraged them to apply for graduate programs. Based on their response to the survey questionnaire distributed to the participants, the students' decision to pursue graduate studies is influenced by their participation in undergraduate research. As compared with the effect of the program in research and internship, the results obtained indicate relatively lower on the students pursuing graduate studies. This can be explained in two ways. The first is some of the mentees were more interested in employment opportunities than pursuing graduate studies. Some of the students indicated that their projected plan is to secure a job first and enroll in graduate school as a part-time status. They were also expecting that the graduate-level tuition expenses could be covered by their employers.

About 100 percent of the respondents in 2018/19 academic year agreed or strongly agreed that being part of the scholarship and research activities under a faculty mentor contributed to the awards, honors, or recognition they received from the institution or professional societies. This is mainly attributed to their strong research experience, publications, and presentations at local, regional, and national scientific conferences. The students also indicated that the monthly stipend and the tuition scholarships provided covered their Fall and Spring semesters living expenses, which provided financial relief, assisted them in focusing on their classes and other

academic activities than spending their time on off-campus employment, ultimately succeeding in their academic endeavor. This is consistent with the earlier work by Swail et al. (2003), which reported that, as compared with minority students taking student loans, those students receiving scholarships from grant projects were found to be more likely to succeed academically and earn their Bachelor's degree.

The survey responses suggest that the financial support and research participation of undergraduate students with faculty members could improve retention efforts, enhanced students' credentials to secure employment, and encouraged them to consider graduate education in STEM fields. The scholarship program also provided unique research opportunities for undergraduate students to attend local, regional, and national professional conferences, present research findings, which resulted in co-authorship of refereed journal and conference proceedings. This

result agrees with earlier findings, which suggested that advising and engaging minority students in research activities resulted a positive outcome in improving undergraduate students learning experiences and one of the motivational factors for their persistence to earn their undergraduate diploma and pursue graduate education in STEM discipline (Barlow and Villarejo, 2004; Kassu and Sharma, 2019; Russell et al., 2007; Xu, 2018).

Students participated in undergraduate research programs are also found to gain the required research culture and skills, as well as networking opportunities with their peers (McDevitt et al., 2020), which makes them better prepared for graduate school and facilitate their transition into graduate studies, enhance their performance at the graduate level and perform well in their research projects (McDevitt et al., 2020; Gilmore et al., 2015; Collins et al., 2017).

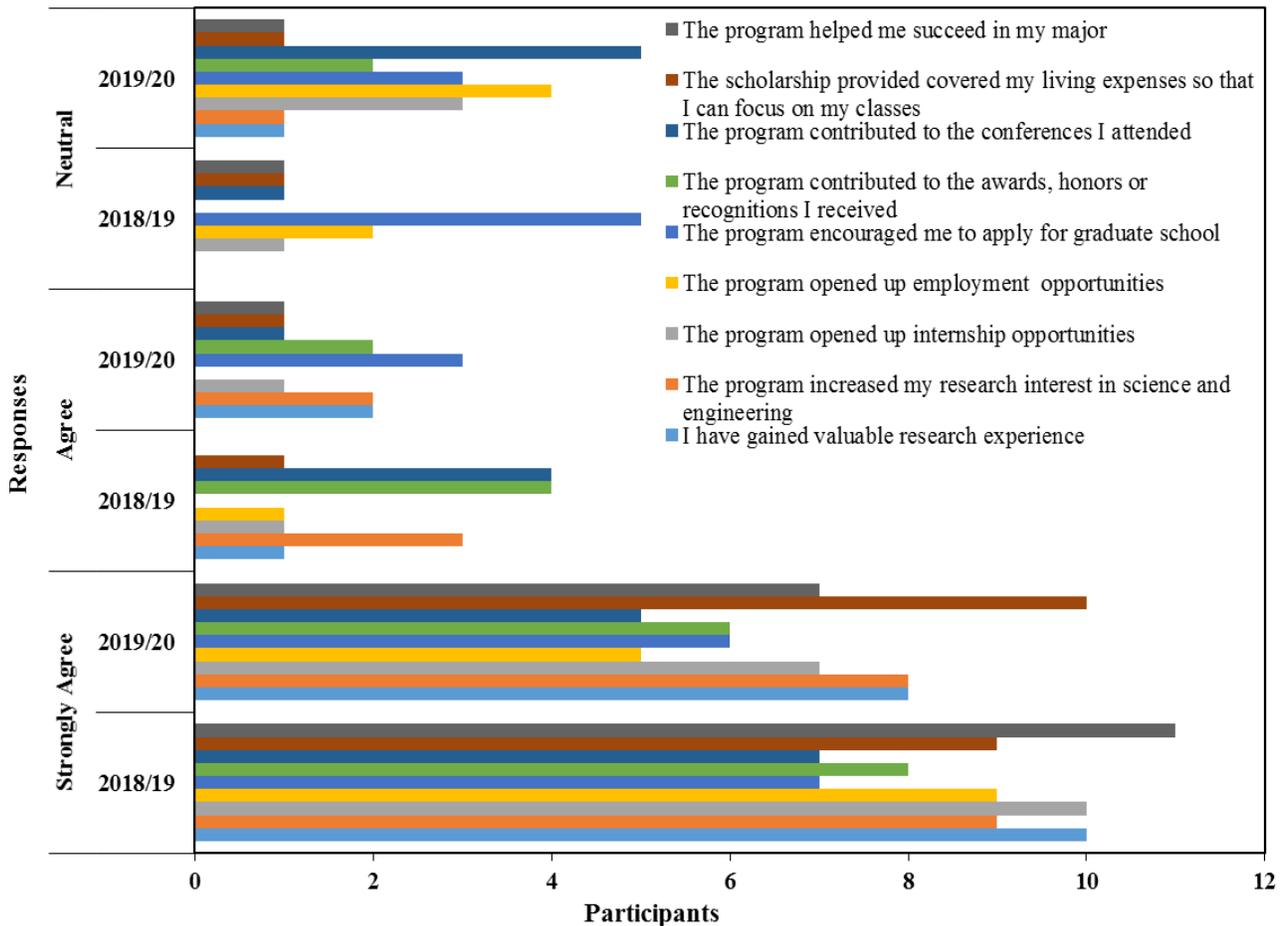


Figure 2. Participants' survey results in 2018/19 and 2019/20 academic years.

■ CONCLUSIONS

In summary, the paper presented the results of the faculty-mentored undergraduate STEM scholarship and research program supported by the Department of Homeland Security-Scientific Leadership Award (DHS-SLA). The program recruited qualified underrepresented minority STEM students from the College of Engineering, Technology and Physical Sciences, and awarded scholarships including monthly stipend and tuition for the fall and spring semesters up to four years. As part of the requirements of the project, all the selected students were assigned to the participating faculty mentors to work on research projects. The selected students were also required to present their research findings to their peers and faculties at the 'End-of-Semester Workshop' series initiated by the project, at the Annual STEM Day event, The Annual Conference of the Alabama Academy of Science, the Annual Emerging Researchers National (ERN) Conference, and other national and regional conferences. Based on the feedback received from the students, besides alleviating the financial constraints, the program provided them several opportunities to work on research projects, attend conferences, co-authorship of refereed articles and conference proceedings, enhanced their resume, facilitated summer internship and co-op opportunities, encouraged them to pursue graduate STEM education and STEM career. Some of the students mentored under this program received prestigious national awards and recognitions for their outstanding accomplishments in the undergraduate research category. The undergraduate faculty-mentored research program also served as a platform for facilitating direct interaction of the students with faculty mentors and other team members in the mentors' laboratory and on-campus and off-campus collaborators and improved access to research laboratories. This effort increased the participating students' research skills and contributed to the students' pursuit of professional STEM careers in their major area. The program also increased their research skills and developed the next generation of underrepresented minority STEM professionals. Due to repeated lack of participation and attendance in the faculty-led research activities and the end-of-

semester seminar series, one student was terminated from the scholarship and mentoring program.

■ DECLARATIONS

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Competing interests

The author declares no competing interests.

Consent to publish

Not applicable.

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