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Promoting Undergraduate STEM Education at a Historically Black College and University through Research Experience

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Supporting Information

ABSTRACT: Diversification of our country's science talent pool is critically needed and can only be achieved by stimulating interest in science, technology, engineering, and mathematics (STEM) among students from a wide variety of cultural backgrounds. However, motivating, increasing the number, improving retention rates, and graduation rates of underrepresented minority (URM) students in STEM disciplines continue to be a major challenge and of active pedagogical interest to historically black colleges and universities (HBCU). Early involvement of URM students in research is a viable strategy to excite minority students in STEM areas. This work reported the use of the Raising Achievement in Mathematics and Science (RAMS) scholar and Summer Undergraduate Research Experience (SURE) programs at Winston-Salem State University (WSSU) as a strategy for promoting and stimulating the interest of URM students in STEM education at a HBCU institution. The influence of the RAMS scholar and SURE programs on the retention rate and STEM education of the URM students was examined. The experience of RAMS scholars and SURE participants was also evaluated by administering a survey to the participants upon completion of the program. The retention rates of the RAMS scholars and SURE participants were better than that of non-RAMS scholars or non-SURE participants. The analysis of the survey results indicated that the RAMS scholar and SURE programs clearly generated URM student excitement, while promoting critical thinking, teamwork, and leadership skills. Moreover, RAMS scholars and SURE participants particularly enjoyed other program enrichment activities, including professional development seminars and social activities as well as poster and oral presentations at regional and national conferences.

KEYWORDS: *Professional Development, First-Year Undergraduate/General, Second-Year Undergraduate, Upper-Division Undergraduate, Analytical Chemistry, Hands-On Learning/Manipulatives, Inquiry-Based/Discovery Learning, Undergraduate Research, Student/Career Counseling, Student-Centered Learning*

INTRODUCTION

Many studies have shown a continued large disparity between the retention and graduation rates of underrepresented minority (URM) students majoring in science, technology, enginerring, and mathematics (STEM) fields compared with nonminority student STEM majors.[1-9] This disparity is of a considerable concern in higher education, particularly in undergraduate historically black colleges and universities (HBCU). Effective training of more URMs in STEM disciplines is of considerable national interest to promote and strengthen the future quality of our educational system and technical workforce, which is critically needed in order to compete in today's global economy. However, the development of strategies to motivate, excite, and retain URM students in STEM disciplines continues to be a major challenge and of active pedagogical interest to HBCUs.

The overall retention rates and four-year graduation rates at HBCUs are generally low and may be due to various reasons including financial issues, inadequate student preparation for college, health, lack of motivation, and family problems. Retention rates in the STEM disciplines at WSSU is also of great concern.[10] In 2008, the first-, second-, third-, and fourth-year retention rates for first-time full-time first-year students were, respectively, 77.8%, 61.9%, 56.8%, and 35.4%, with an average four-year graduation rate of 17.3% at WSSU.[10] The average four-year graduation rate for STEM majors was 9.3%.

Many strategies, including adequate provision of financial aid information, work study, and research assistantships, have been provided to students to minimize the distraction from off-campus jobs. Additionally, supplementary instruction in gatekeeper STEM courses, tutoring, recitation, mathematics review, and the use of active-learning techniques including guided inquiry (GI), process-oriented-guided-inquiry learning (POGIL), and problem-based learning (PBL) have been strategically developed to motivate and improve student success in the STEM fields at WSSU.[11] Studies from other institutions have also reported the utility of several strategies, including peer-led team learning, collaborative learning, chemistry merit goal, tutorial assistance, effective mentoring, financial support for economically disadvantaged students, action-learning classrooms, flipped classrooms, the use of active feedback through the internet, GI, and POGIL for promoting student learning

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and for improving student retention rates in STEM.[12-31] Early participation of URM students in research is another viable approach to readily motivate and excite students in STEM areas.[32-36] Students who participate in research early, during the first year and second year, are more likely to succeed and graduate with college degrees in STEM disciplines. Such students are also likely to advance to graduate school in STEM areas or proceed to professional schools. Accordingly, WSSU is proactively engaging its students in research and scholarly activities during the academic year and the summer to improve student learning in STEM areas. This work reports the use of the fall 2009 funded National Science Foundation Historically Black Colleges and Universities Undergraduate Program (HBCU-UP) project, the Raising Achievements in Mathematics and Science (RAMS) project, to improve the retention rates and to promote student learning and student success in STEM education.

RAMS Scholar and SURE Programs

The RAMS Scholar and the SURE programs are two components of the HBCU-UP RAMS project with three primary objectives. The first objective of the project was to increase the number of STEM majors and their retention and graduation rates. The second objective was to improve undergraduate research capacity, and the third was to increase the number of STEM graduates who matriculate into graduate programs. A total of 88 students have participated in the RAMS scholar program between Fall 2009 and Spring 2013 (Table 1).

Table 1. Distribution of RAMS Scholars and SURE Participants from 2009 to 2013

	N	
Project Year	RAMS Scholar Participants	SURE Participants
2009−2010	12	22
2010−2011	17	20
2011−2012	28	21
2012−2013	31	16
Total	88	79

The scholars are comprised of 47 biology majors, 26 chemistry majors, 7 computer science majors, and 8 mathematics majors. There is no engineering program at WSSU; therefore, no engineering students were included in the RAMS scholar or SURE programs. Participants were assigned to work for 8−-10 h/week with a faculty mentor to conduct research of mutual interest for the academic year. Each scholar received a $2,400 stipend for one academic year but may be renewed for another year. To qualify as a RAMS scholar, the student must be a first-year or second-year STEM major and have a GPA of 3.0 or higher. However, first-year students and students with GPA of less than 3.0 who expressed strong interest in research and graduate studies in STEM have also been admitted into the RAMS program.

The SURE program was also organized to engage students in research during the summer and ultimately to increase the participation of URM students in STEM at graduate levels and in the STEM workforce. The program was open to all STEM majors regardless of classification. A total of 79 (33 males and 46 females) students and 45 research mentors have participated in the SURE program between 2009 and 2013 (Table 1). The SURE participants were made up of 38% first-year, 33% second-year, 27% third-year, and 2% fourth-year students. To promote the participation of community college students in research and to facilitate smooth transfer of students into four-year college STEM programs, Forsyth Technical Community College (FTCC) students interested in obtaining a STEM degree were also admitted into the SURE program. The FTCC students constituted 11% of the SURE participants.

Each SURE participant was assigned to a faculty mentor on a project over a period of 6 weeks. The participants received a $2,400 stipend and room and board for those who needed it. All SURE students must be STEM majors, have a strong interest in attending graduate school, and possess a minimum GPA of 3.00. Along with a small honorarium, limited research supplies and support to attend conferences were also provided to the research mentors. Speakers from graduate and professional schools were invited to give seminar presentations on various research topics and also to inform the SURE participants about the admissions process and scholarship opportunities available at their institutions for prospective graduate students. Seminar presentations on laboratory safety, ethical conduct in research, scientific writing, and poster presentation were also provided. Social activities, including, a movie and pizza night and bowling were incorporated into the SURE program to promote social interaction and networking between the SURE student participants and faculty mentors in an informal setting.

The RAMS scholars and SURE participants were required to submit a full written research report at the completion of the program. SURE participants gave poster presentations of their work at a culminating closing ceremony. The poster presentations were judged and awards were given to the top three presenters. Certificates were presented to all participants and their mentors at the ceremony. Both the RAMS scholars and SURE participants were also required to present their research at the WSSU Scholarship Day held each spring. Presentations by undergraduate students at national research conferences are highly beneficial;[17] therefore; the RAMS scholar and SURE participants were also encouraged and supported to present their research at regional and/or national professional conferences. The HBCU-UP program also encouraged participants to seek summer research opportunities at other institutions and national laboratories in order to further strengthen their research experience. To evaluate the overall student experience and the success of the RAMS scholar and SURE programs, a voluntary survey was administered to the participants at the end of the program. The survey data were collated and analyzed.

RESULTS AND DISCUSSION

Influence of RAMS Scholar and SURE Programs on STEM Education at WSSU

As stated earlier, the 2008 four-year graduation rates for first-time full-time first year students at WSSU were generally low (17.8%). The graduation rates were even lower for STEM majors (9.3%). Retention rates for first-year (77.8%), second-year (61.9 %), third-year (56.8%), and fourth-year (35.4%) students were observed at WSSU in 2008. The first year (47.5%) and second-year (34.4%) retention rates were recorded for STEM majors at WSSU in 2007. Similar first-year (48.5%) and second-year (29.6%) retention rates were obtained for STEM majors in 2008. In contrast, a high retention rate for RAMS scholars after year 1 of 98.8% was

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observed. The retention rate of RAMS scholars of 98.8% was maintained after year 2, year 3, and year 4. In fact, less than 1% of the 88 RAMS Scholar program participants dropped out of the program due to GPA, research schedule problems, or change in full-time status. Consequently, the RAMS program has improved students' retention rates and enhanced student learning and success in STEM education at WSSU. It is of considerable interest to note that the entire 2009 RAMS scholar cohort has graduated in STEM disciplines (with graduation rate of 100%) and are currently enrolled in either M.S./Ph.D. graduate programs or professional schools.

The HBCU-UP program has also recruited students from FTCC into the SURE program. Participation in the SURE program has provided the community college students with research experience not available at FTCC, while facilitating interaction with students and faculty at WSSU and easing the transition for those enrolling at WSSU. This partnership between WSSU and FTCC through the SURE program has facilitated the transfer of two FTCC student SURE participants into the STEM disciplines at WSSU. Another three FTCC participants have enrolled in four-year degree programs in STEM majors at the University of North Carolina, Greensboro and at West Virginia. Furthermore, one FTCC student SURE participant has been admitted into a medical school. In addition, the RAMS Scholar and SURE programs have improved students' communication (both oral and written) skills. All SURE participants have given poster presentations of their research findings at the closing ceremony and during WSSU Scholars Day. Participants were also encouraged and supported to present their work at regional and/or national conferences. The list of the conferences attended and the number of poster and/or presentations by the RAMS scholar and SURE participants locally or at regional and national conferences are provided in Table 1 of the Supporting Information. More importantly, RAMS scholar and SURE research participation has also resulted in five peer-reviewed journal publications. Please see the Supporting Information for detailed information of the peer-reviewed publications listing the RAMS scholar and SURE participants as co-authors. A number of RAMS scholar and SURE participants have also gone on to other research-intensive institutions in order to further their research experience. The lists of the off-campus summer research experiences are provided in Table 2 of the Supporting Information.

Evaluation of Student Experience of the RAMS Scholar and SURE Programs

To evaluate the overall student experience of the RAMS scholar and SURE programs, a voluntary survey (Table 3 in the Supporting Information) was administered to the participants at the end of the program. The analysis of the program survey indicated that 88% of the participants found their projects very interesting and exciting. Also, 88% of the students strongly agreed or agreed that they were mentally challenged by their projects. Additionally, 91% of the participants strongly agreed that their projects considerably enhanced their critical thinking and ability to work independently. Also, 76% of the participants reported that the RAMS scholar and SURE programs significantly improved their written and verbal communication skills and increased their level of confidence. More importantly, 94% of the participants reported the program strongly motivated them toward future research, and 79% of the participants strongly agreed that the program strengthened their spirit of teamwork. Some of the direct student comments from the program survey are presented as follows:

"I appreciated my research project because it can be applied to drug design which is associated with my career choice: pharmacy"

"this program was a good experience. It was financially helpful and the research helped me understand my major more"

"this program was helpful in introducing me to a new area of research in my field of study". "The experience I have gained will be used in my future and will help me enhance my resume"

"It is a very good program that helps us to research and help me to take what I did to upper level"

"this was my first time of doing research. I enjoyed it and learned a lot. I look forward to doing future research"

"I found most of the seminar activities were informative and helpful"

"this was my first time ever doing research and I found that it was very interesting and challenging at the same time. But it was good and a great opportunity"

"I truly enjoyed my experience with RAMS and since this program I have furthered my interest in research at many different schools"

The achievements and research progress made by STEM students in the RAMS program will be sustained beyond 2014 when National Science Foundation (NSF) funding ends. Winston-Salem State University has institutionalized academic year and summer undergraduate research experience through the creation of the Undergraduate Research Office. This program was initiated while the RAMS program is on-going. The primary goal of the program is to further sustain undergraduate research. The research program is open to students in all majors and targets newly admitted first-year students for research experience.

■ CONCLUSION

Overall, the RAMS scholar and SURE programs at WSSU were very successful in stimulating the participation of underrepresented students in research activities in STEM disciplines. The broader impact of the programs is the development of highly trained human resources through the production of well-prepared graduates to meet the needs of our society, which is increasingly dependent on the progress made in science and technology. The RAMS scholar and SURE programs have increased retention rates of the participant cohorts in STEM fields at WSSU. In addition, the programs have improved the critical thinking, problem solving ability, communication skills, and confidence levels of underrepresented students. This will ultimately promote diversification of our country's science talent pool which is critically needed and can only be accomplished by stimulating interest in science among students from a wide variety of cultural backgrounds.

■ ASSOCIATED CONTENT

Supporting Information

Text describing presentations at local, regional, and national conferences, research experience at other institutions, and selected student quotes about the RAMS and SURE program and tables listing the numbers of presentations regionally and nationally and peer-reviewed publications listing the RAMS scholars and SURE participants as co-authors, numbers of

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students in off-campus research participation, and the student's evaluation for the RAMS scholar/SURE program. This material is available via the Internet at http://pubs.acs.org.

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Notes

The authors declare no competing financial interest.

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