Enhancing Undergraduate Bioscience and Engineering Education at North Carolina A&T State University through Curriculum Integration and Research Experiences

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INTRODUCTION

Compared to the percentage of undergraduates at majority institutions who pursue graduate degrees and professional career fields in scientific research, African-Americans are underrepresented. Our institution, North Carolina A&T State University (NC A&T), is a large HBCU with over 2,000 STEM majors, of which approximately 95% are African-American. With an ever-increasing gap in the educational backgrounds and academic abilities of incoming freshman, faculty members are presented with the dilemma of how to engage students in a manner that increases their potential for success. We believe that high-impact, authentic student research experiences, coupled with curricular integration across STEM disciplines, is a key component necessary to transform undergraduate bioscience and engineering education at NC A&T.

Overview of the I3/iBLEND Program

The Integrative Biomathematics Learning and Engagement Network for Diversity (iBLEND) project at North Carolina A&T State University, which began in 2004, prepares students for graduate study at the interface of biology, mathematics and engineering. The iBLEND project supplies both a physical and virtual intellectual setting where students find a sense of identification, belonging, responsibility, and achievement for leadership and service roles in biomathematical research careers. In 2009, iBLEND was integrated into the larger ICUBED (I3) project, which introduces new areas of research to faculty and graduate students through their involvement with undergraduate research projects that focus on the emerging interdisciplinary fields of systems biology and synthetic biology. Importantly, I3 initiatives bridge engineering and biology programs at North Carolina A&T State University. For instance, the International Genetically Engineered Machines (iGEM) project at NC A&T is a student-driven synthetic biology initiative where students from multiple departments seek to re-purpose and re-engineer biological systems to execute novel functions. Due to their cross-disciplinary nature, systems biology and synthetic biology are useful means of connecting modern biology principles with the disciplines of engineering, chemistry, computational science and mathematics.

GOALS of the I3/iBLEND program:

- Promote innovative programming, policies, and practices to encourage the integration of STEM research and education
- Expand the impact of NSF-funded projects on undergraduate education
- Provide additional avenues to broaden participation for underrepresented STEM students
- Increase synergy and collaboration across NSF and non-NSF-funded projects to provide an integrated experience to students.

Undergraduate Research as a Vehicle for Change

One of the fundamental goals of the I3/iBLEND program is to promote undergraduate research and scholarly productivity through engagement with faculty to improve student understanding of content and to promote mastery of technical skills at the intersection of biology, chemistry, mathematics and engineering. We view undergraduate research as a catalyst for student success across gender, ethnicities and disciplines. Therefore, in parallel with curricular changes, we have increased the visibility of transformative research occurring at the interface of STEM disciplines. To accomplish this, we have spearheaded a faculty alliance across academic departments at NC A&T. This cross-departmental strategy has engendered a force-multiplier effect that increases institutional synergy to provide underrepresented minorities with opportunities to translate their learning into career paths in the biosciences. Hence, there has been a rise in faculty members within these departments who are acting as agents of change, both among our students and those across the campus, for incorporating innovative research experiences into STEM curricula. An understanding of research findings will require our students to do translational research at the interface of engineering, mathematics, computational science and biology. Therefore, in addition to formal "wet" laboratory research training, interested students also receive hands-on training with computational, simulation-based and data analysis tools during their projects. These projects allow students to engage in faculty mentored research throughout the year, both on and off the campus, and to develop cross-disciplinary research skills that enhance their post-graduate career opportunities.

The effectiveness of teaching and research training programs is evaluated annually by an external assessment group to survey and track academic performance of students and to follow their participation in research and readiness for summer internships and graduate school. Early indicators in several areas suggest that the two-pronged approach outlined above is positively impacting student success (**Figures 1-3**).

Creating Research Opportunities for Undergraduates

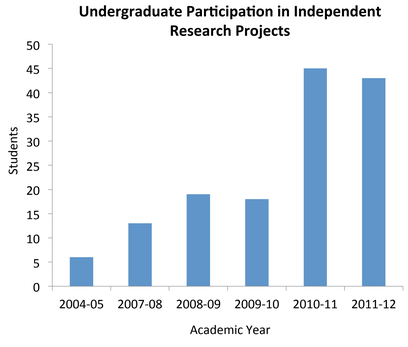


Figure 1. Increasing access to independent research opportunities for undergraduates. The number of students participating in independent research projects annually has increased more than five-fold over last eight years, due in large part to the NSF-sponsored I3/iBLEND program.

Promoting Participation within the Scientific Community

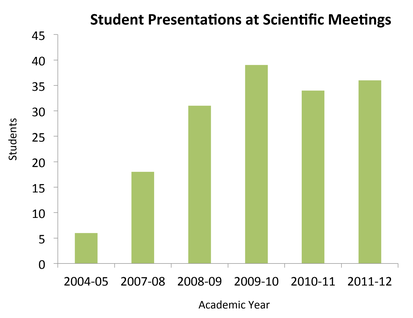
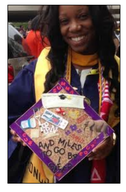


Figure 2. Student presentations at research conferences. Over the past eight years, the number of undergraduates presenting papers at scientific meetings has steadily increased (right). Moreover, for the past three years, several of our students earned awards and honors at these national and international conferences (bottom left). Importantly, the increased focus on undergraduate research has also led to a significant increase in the number of faculty/student-co-authored papers.

Preparing Students for the Next Step



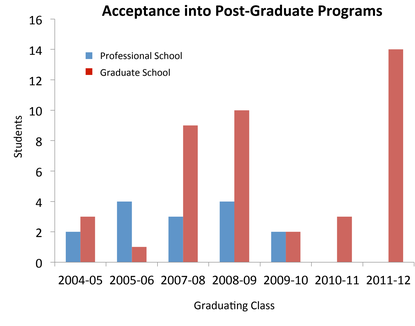


Figure 3. Acceptance into post-graduate research programs. Student acceptance rates into masters and doctoral programs at research intensive universities has increased dramatically during the course of the I3/iBLEND program (right). Representative universities where recent alumni of the I3/iBLEND program are currently pursuing Ph.D.'s are shown (bottom left).

Building Bridges On Campus and Across the Country

Figure 4. Introducing students to research opportunities. (Left) Together with the MARC program, the I3/iBLEND program hosted the 1st annual MORE STEM Fair designed to provide students with information about summer research programs and graduate school admissions. The event was attended by over 100 participants and attracted representatives from, among others, Duke, UNC-CH, Emory, NC State and Yale. (Right) The I3/iBLEND program has helped support student research initiatives through cross-institutional programs, such as workshops and internships in bioinformatics at the Pittsburgh Supercomputing Center (above) and a joint iGEM synthetic biology team with the University of Texas, Austin.

Synergizing NSF- and Non-NSF-funded Projects at NC A&T

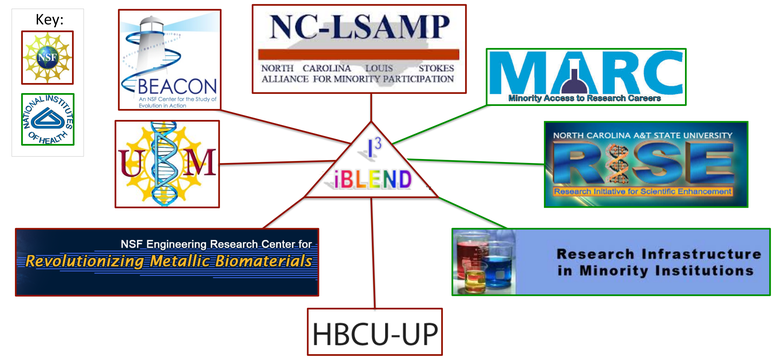


Figure 5. Institutional Integration. Through the I3/iBLEND program, we have successfully integrated a number of funded endeavors at NC A&T and jointly-created long-term research experiences for interdisciplinary teams of students. NSF-sponsored programs are outlined in red while NIH-sponsored programs are outlined in green.

Building on Momentum and Sustaining Change

The I3/iBLEND program represents a proactive, intensive approach designed to bridge campus chasms by positively influencing academic programs through interdisciplinary training and strong evaluation and assessment. We routinely get feedback from math and biology faculty, including data regarding the status of interdisciplinary courses and accomplishments in connecting the curricula. We are highly interested in knowing to what extent students are exposed to problem-based, active learning activities and appropriate technology in their courses, particularly those courses taught by the primary engineering, mathematics and biology instructors. In this regard, student surveys are key. We assess and evaluate students' exposure to relevant technology, problem solving skills, higher order thinking, and ability to make explicit connections to engineering, biology and mathematics areas. These data show that as an immediate outcome of I3/iBLEND efforts, an increasing number of undergraduates have actively engaged in hands- and minds-on research. Moreover, significantly more underrepresented students from our campus are strongly motivated to continue graduate research. The data suggest that core lab clusters facilitated by I3/iBLEND were key contributors to more students taking the GRE, scoring at competitive levels, and/or applying for graduate school. Through new partnerships between biology, mathematics and engineering, we envision major steps forward that will improve and expand research and training within the culture of an HBCU. As a tangible outcome, I3/iBLEND faculty view mentoring research students as a part of their normal duties and responsibilities and one that brings prestige to the student, the faculty, and the university. A greater number of potential and currently-enrolled NC A&T students now recognize our university as an institution that prepares students for interdisciplinary research careers.

Acknowledgments

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