NCAT-CORNELL PREM SEED PROJECT: INCLUSIVENESS STRATEGY AND RESULTS

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The North Carolina Agricultural and Technical State University (NC A&T)-Cornell University Partnership for Research and Education in Materials (PREM) was a successful three-year project funded through NSF seed grant funding. The partnership was established to create a productive collaboration with Cornell as a Predominately White Institution (PWI) and North Carolina A&T State University as a Historically Black College and University (HBCU). The ultimate goal of the project was to create a pathway for graduate and undergraduate Science, Technology, Engineering, and Math (STEM) students and to broaden participation of underrepresented students and faculty members in materials research. The NC A&T-Cornell PREM partnership focused primarily on implementing strategies to meet the NSF PREM expectations of creating new opportunities for students, enhancing research productivity and infrastructure, and developing integrated research and education programs at NC A&T. The central component was engaging students in state-of-the-art materials research and education endeavors along with culturally responsive mentoring which created a Culturally Responsive PREM Pathway.

Need for more students in materials science and STEM: The National Science Foundation (NSF) has indicated that creating a strong STEM workforce is a national priority to maintain "the nation's standard of excellence and global leadership in STEM" [1]. In addition, to growing the current and future STEM workforce, there was also considerable interest in the utility of multiple perspectives within the workforce so increasing and broadening participation has also been a national imperative [2]. However, despite numerous and ongoing initiatives aimed at increasing STEM interest and participation among marginalized communities and women, many STEM areas, such as engineering and materials science, remain largely homogenous [3], [4], [5]. This is increasingly problematic as the demographic composition of the United States continues to shift [3].

Theoretical framework

The creation of a Culturally Responsive PREM Pathway was grounded in Social Cognitive Career Theory (SCCT), which highlights the importance of self-efficacy in shaping academic and career interests [6] This career development model describes an individual's career development and career choice processes as being influenced by person variables (i.e., gender, race, etc.), environmental influences (i.e., financial resources, mentors, etc.), and learning experiences (i.e., exposure to STEM content) which in turn influences career self-efficacy, career interests, decision making, career goal setting, and outcome expectations. It also includes consideration of contextual supports and barriers (i.e., family support) as influential on career development outcomes [7].

Social Cognitive Career Theory is widely adopted in research on student success in STEM, including examinations of gender, race, and ethnicity in engineering [8]. The framework has been successfully applied to STEM education and minority students [9], mentoring [10], [11], persistence in STEM [12], [13], STEM interest [14], academic success, satisfaction, and engagement [15], and career commitment in STEM [16]. In short, this theory has shown great utility in understanding the career development, progression, and persistence within STEM fields [17].

When looking specifically at underrepresented communities in science, it is important to recognize that this most typically refers to racial minorities and women but also includes individuals with disabilities, economically disadvantaged, and others. In considering these groups and their lack of representation in STEM fields, it is important to understand the supports and barriers that these communities often experience which impacts their decision to select and persist in STEM fields. Some common student barriers that have been identified include issues with access, departmental climate, and institutional practices [18], presence of negative interactions within the STEM department [13], and a lack of identity safety cues and visual representation [19]. Conversely, academic support [18], supportive STEM relationships [20], sense of belonging [21], [5], [22], authentic learning experiences and research opportunities [3], [16], [23], social capital, social cohesion, and representation [23], and welcoming and supportive mentors [3], [13] aids in the development of STEM identity which can predict STEM persistence.

Inclusiveness strategy and creation of a culturally responsive STEM pathway

Building upon the existing research outlined above, the PREM and MRSEC PIs for met weekly to share strategies for creating a Culturally Responsive STEM Pathway. Factors that shaped the pathway were access to learning experiences and research, culturally responsive and accessible mentoring, building a supportive community with representation, and creating a sense of belonging. A central component of the pathway was student engagement in state-of-the-art materials research and education endeavors. The availability of the preeminent researchers and world-class scientific infrastructure of the Cornell Materials Research Science and Engineering Centers (MRSEC), along with culturally-responsive mentoring and community building, propelled the students to successful progression on the PREM pathway. As a result, the following strategies were successfully designed and implemented.

Young scholars and summer learning programs

The project provided stipends for high school students (N=4) to participate in PREM research projects in a developmentally appropriate way. These scholars were recruited through outreach efforts in K-12 schools by way of teacher, PI, and PREM staff outreach. Students came from public high schools including a STEM focused Early College high school. Of these scholars, 100% were male and 50% were URM (Underrepresented Minority). Not only did this experience give these students exposure to hands-on materials science/STEM topics and research but also served as a recruitment tool to pursue further study into these areas. Of these students three successfully graduated (N=3) by the project end date and went on to major in a STEM discipline (e.g., Chemistry).

Additional outreach efforts included sharing Cornell University teaching toolkits to teach fundamental STEM concepts in a teacher-led experiential classroom. These toolkits were also utilized during summer immersion experiences for NC A&T TRiO students. This undergraduate student population is an outreach and service program administered by the Department of Education to provide assistance and support to first-generation, low-income, and disabled students. Participants were first year undergraduate students and their experiences were designed

to increase exposure to and interest in careers in STEM. At the conclusion of these experiences, students did report their interest in these areas had increased as a result of this programming and several indicated a desire to major in engineering.

PREM module and course development for recruitment at the undergraduate level

Each semester for the duration of the project, jointly developed teaching modules (N=8) were developed and deployed by the PREM PIs in their respective science and engineering undergraduate courses. These modules typically consisted of a course lecture or activity related to a materials science topic designed to stimulate interest in the materials science field. It is important to note that materials research was shared at a developmentally appropriate level and at the appropriate stage of the course. Group and individual visits to the PREM labs were also arranged and financial opportunities related to materials science careers were shared as well. Two jointly taught courses (N=2) between NC A&T and Cornell PREM PIs were also developed and launched during this project.

Several students who participated in these activities then self-selected to enter the PREM pathway (N=12). These students then became eligible to participate in co-sponsored Joint Materials Science Workshops (N=2) conducted by the PIs as well as monthly meetings with the PIs. 50% of these students in the pathway were female and 100% were URM. These students were encouraged to pursue direct admission to a PhD after their B.S. degrees were awarded.

Recruitment strategies at the graduate level

Graduate student recruitment strategies were multifaceted. To recruit new students to the program and the institution, a digital marketing campaign was implemented with a recruitment video and in-person recruitment exhibits at select science and engineering conferences. NC A&T PREM PIs staffed these recruitment events and engaged prospective students individually. All recruited students were eligible to receive Department of Education Title III Strengthening Historically Black Graduate Institutions (HBGI) funding to pursue their STEM studies. For students already matriculating at the institution, PREM research related seminars were presented to graduate students in different departments. They also received exposure to PREM-MRSEC research opportunities through sponsored workshops and guest lectures.

Graduate students who elected to enter the PREM Pathway then participated in the Joint Materials Science Workshops (N=2) previously mentioned and monthly meetings with the PIs. There was also one jointly taught graduate course (N=1) developed consisting of both Cornell and NC A&T faculty. Students were also able to participate in Cornell University's Center for Materials Research (CCMR) research through student visits and summer programming. Ultimately, fourteen graduate students (N=14) were recruited, 8 PhD students (N=8) and 6 master's students (N=6). 50% of the graduate students were female and 71% were URM. Two master's students (N=2) and three doctoral students (N=3) successfully moved through the pathway and graduated with STEM degrees during the three-year project period.

Retention activities:

Individual Development Plans (IDPs) using a researcher-designed template were developed for each student by their research mentor/advisor to help them set both short and long-term goals. This multi-page document was co-constructed by the student and their mentor and included recording accomplishments and goals towards graduation and beyond. This plan was updated at least annually as students met their scheduled targets. As part of this, their mentors kept them actively engaged in research, encouraged them to attend special seminars, promoted them to attend and present papers at conferences, and publish in peer-reviewed journals. Graduate students in the PREM pathway were also assigned to serve as peer mentors for undergraduate students which created a multi-tiered mentoring system. There was also joint thesis/dissertation committee membership between the two partnering institutions. In addition, students provided feedback on each learning module deployed to enable for revision in response to student satisfaction. Ultimately, there was 100% retention for undergraduate (N=12) and graduate students (N=14) in the PREM pathway.

Interacting with MRSEC partner:

The exchange of research, education, and planning ideas took place via in-person visits of students and faculty members as well as electronic media such as Zoom, email, WhatsApp, Box, and conventional phone calls throughout the duration of the seed project. The research of NC A&T students and faculty was profoundly impacted by testing of samples prepared at NC A&T using the Cornell facilities with NC A&T students and faculty present either in-person or remotely (XPS< TEM, STEM, EELS, etc.) and jointly analyzing the research and education results. The meetings between the PREM and MRSEC PIs occurred on a weekly basis. There was proactive involvement of more than 10 Cornell MRSEC faculty and research staff in the NCAT PREM project. This created great synergy and also created a mechanism for not only research collaboration but also for sharing culturally responsive practices.

Summer REU program at MRSEC Partner and faculty/student exchanges

The Cornell MRSEC hosted two NC A&T REU students for one summer and one faculty member for one summer. This exposed these researchers to a larger PREM, as well as different labs and research projects to enhance their own research skills, interests, and accomplishments. It also provided additional exposure to mentors and scientists from a variety of backgrounds. The partnership was further strengthened by faculty and student exchanges annually where at least 4 students and/or faculty visited the partner institution.

Interaction with NSF PREM program managers

The constant interaction of the NC A&T-Cornell PREM team with the NSF-PREM program managers played a key role in the success of the PREM project at NC A&T. These interactions were monthly/quarterly Zoom meetings with the NSF program directors and included frequent sharing of research and educational highlights and accomplishments. The NSF program directors and managers also interacted with PREM team at national conferences such as MRS meetings. These interactions culminated in a site visit by the NSF team to NC A&T campus where they were able to observe and participate in technical research presentations, learn about the culturally responsive PREM pathway, and meet students in-person. Additionally, they were able to meet

campus upper administration, tour the PREM labs, participate in a student poster session, and meet all members of the PREM team.

Incorporating feedback from the external advisory board

The project established an External Scientific Advisory Board (ESAB). The ESAB members were from different institutions and included two members from a PWI and one from an HBCU. The faculty serving were from Chemistry and Biochemistry, Physics and Astronomy, and Chemistry. The ESAB met annually and were presented with research accomplishments, project progress, and had the opportunity to meet and interact with participating PREM Pathway students.

Continuous improvement and strategies to assess inclusiveness:

A significant part of this project was assessment and continuous improvement. The numbers and types of interactions between Cornell and NC A&T faculty and students was recorded. Students who experienced a PREM activity or were actively in the pathway were assessed using digital surveys which measured satisfaction with the PREM activity/experience, interest in materials science/STEM, and student self-efficacy in these areas. Additional elements assessed were diversity enhancement that resulted from recruitment and retention activities.

Fostering cutting edge research

This project yielded high research productivity. Ultimately, at the end of the 3-year project, there were fifty-two presentations in local, national, and international conferences (N=52) conducted by PREM students and partnering faculty. In addition, there were 7 high impact publications including the *Journal of Applied Physics* and *AIP Advances*. The Cornell and NC A&T PREM research teams went on to develop a $10.3 million dollar joint PREM proposal. While this proposal was not funded, using the foundation and knowledge gained from this PREM seed project, NC A&T did receive a fully funded PREM in 2024. Also of note is that the researchers on the NC A&T PREM were awarded Research Team of the Year by their institution in 2025 for their ongoing PREM work.

Outcome of the NC A&T-Cornell partnership

The PREM has impacted the research and education of 14 graduate students (8 PhD, 6 MS) (URM: 57%, Female: 43%), 13 Undergraduate students (URM: 100%, Female: 77%), 4 high school students (URM: 25%), and 14 faculty members (URM: 50%, Female: 28 %) at NCAT. The PREM has also impacted over 500 students (URM: 80%, Female: 32%) via jointly teaching materials-related undergraduate and graduate new courses/course modules, organizing seminars, and conducting joint materials workshops. The broader impact of this work has been consistently reflected in the project's assessment data, where 97% of participants reported that their STEM interest level had increased, and 53% reported their materials science interest level had increased. This is a broad impact given the interest and awareness of materials science was low prior to the project start. The collective efforts of all faculty participants at both institutions, the External Advisory Board, the NSF program managers, and the students at every level all

contributed to these successes. The additional support available to the PREM students from NC A&T institutional resources in terms of tuition, teaching assistantships and travel support via NSF-initiated mechanisms, such as MRSEC/PREM-sponsored workshops/conferences, has made it possible to support a larger number of graduate, undergraduate, and high school students than initially expected. Of special note is the retention rate for students at all levels was 100%, meaning no PREM students left the PREM program without completing their respective degrees.

Conclusion

The project was extremely successful given the parameters of the limited seed funding. Not only were hundreds of students exposed to materials science but 30 entered the PREM pathway either at the high school, undergraduate, or graduate levels. Most importantly, the utility of the Culturally Responsive PREM Pathway was validated. This pathway created active learning experiences and research opportunities [16], a community of supportive mentors [3], [13], a sense of belonging [21], and social cohesion and visible representation [23] for underrepresented students. While the project spanned a time of three years, the foundation for STEM and materials science identity and persistence was created for these individuals.

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