ASEE AMERICAN SOCIETY FOR ENGINEERING EDUCATION

Paper ID #49566

Exploring Early-Stage Research Experiences Among Underrepresented Minority Students in Aerospace Engineering

Mengqi Monica Zhan, University of Texas at Arlington

MONICA ZHAN Dr. Zhan serves as an Associate Professor for the Department of Communication at the University of Texas at Arlington. Her research interests include employee communication and corporate communication. Recently, she has developed growing interests in underrepresented minority student and employee experiences.

GRACE BRANNON Dr. Brannon serves as an Associate Professor for the Department of Communication at the University of Texas at Arlington. Her research interests include communication pathways affecting specific outcomes (e.g., health, educational major choice) among marginalized populations.

LIWEI ZHANG Dr. Liwei Zhang serves as an Assistant Professor in the Department of Mechanical and Aerospace Engineering at the University of Texas at Arlington. Her research interests includes fluid and combustion physics, propulsion engineering, computational science, and engineering education.

FRANK LU Dr. Lu is a Professor in the Department of Mechanical and Aerospace Engineering at the University of Texas at Arlington. His research is in high-speed aerodynamics and propulsion, primarily in novel detonation engines.

Grace Ellen Brannon, The University of Texas at Arlington
Liwei Zhang, The University of Texas at Arlington
Frank K. Lu, The University of Texas at Arlington

Session XXXX

Exploring Early Research Experiences Among Underrepresented Minority Students in Aerospace Engineering

Monica Zhan, Grace Brannon
Department of Communication
University of Texas at Arlington

Liwei Zhang, Frank Lu
Mechanical and Aerospace Engineering Department
University of Texas at Arlington

Introduction

The underrepresentation of minority students in STEM fields has been a persistent challenge in both academia and industry. This disparity is particularly evident in aerospace engineering programs, where women and students of color are significantly underrepresented compared to national demographics and the overall student population in U.S. public universities [4]. Research experiences for undergraduates have emerged as a promising strategy to address this issue by providing underrepresented minority (URM) students with opportunities to engage in cutting-edge research and develop crucial skills for success in the field [12]. These experiences expose students to aerospace research projects and help them build a supportive community of peers and mentors, which is critical for their persistence in graduate programs and/or careers. The impact of such programs extends beyond skill development, as they also play a crucial role in fostering self-efficacy and sense of belonging in the aerospace engineering community. This is particularly important given that URM students often face additional challenges, including imposter syndrome and a lack of representation among faculty and industry professionals [1]. Furthermore, the intersectionality of marginalization based on ethnicity and social class compounds the challenges faced by URM students, making it essential to consider multiple dimensions of identity when designing support systems and interventions.

As the aerospace industry grapples with diversity and inclusion issues, understanding the factors that contribute to URM students' success and retention in aerospace engineering programs is vital for developing effective strategies to build a more diverse and inclusive workforce in the field. By providing structured research experiences that balance faculty guidance with student autonomy, undergraduate research experience programs can help URM students develop a stronger STEM identity and increase their likelihood of persisting in aerospace engineering careers. This study examines how early-stage research experiences influence URM students' self-efficacy and sense of belonging in aerospace engineering research. Drawing on multiple theories, we explore the impact of engaging in research projects where students select from predefined topics within a larger project area, thus balancing faculty guidance with student autonomy.

Early-Stage Research Experiences and Self-Efficacy

Self-efficacy, or one's belief in their ability to succeed, is crucial for academic persistence [2, 13]. Defined as an individual's belief in their ability to organize and execute courses of action required to achieve goals, self-efficacy significantly influences a student's motivation, effort, and resilience in academic settings [2]. Research has consistently demonstrated a positive relationship between self-efficacy and academic persistence, with higher levels of self-efficacy associated with increased perseverance in the face of academic challenges [14]. Students with high self-efficacy are more likely to tackle difficult tasks, exert greater effort, and maintain persistence when confronted with obstacles [3]. This relationship is particularly significant for URM students in STEM fields, where self-efficacy is significantly correlated with the choice of and persistence in science or engineering majors [10]. Understanding the role of self-efficacy in academic persistence is crucial for developing effective interventions and support systems to enhance student retention and success in higher education.

Moreover, self-efficacy is not a fixed trait but a malleable belief that can be influenced by various factors, including successful mastery experiences, vicarious experiences, social persuasion, and physiological and emotional states [2]. Structured research experiences that offer partial autonomy allow URM students to develop technical skills while fostering a sense of ownership over their work, thus reinforcing their self-efficacy. Research shows that such experiences enhance students' cognitive, personal, and professional gains [19]. Specifically, engaging in research with partial autonomy enables students to make meaningful decisions within a supportive framework, thereby enhancing their sense of ownership. This balance between guidance and independence is particularly beneficial for URM students, as it helps them navigate challenges while experiencing the direct impact of their contributions, thereby reinforcing their belief in their capabilities and mitigating feelings of imposter syndrome [19]. This approach also aligns with Self-Determination Theory (SDT), which posits that supporting autonomy is critical for human flourishing and leads to better engagement, performance, and well-being outcomes [6]. According to SDT, autonomy, competence, and relatedness are key psychological needs for all individuals, irrespective of their background; extensive research has examined applications of SDT in promoting self-determination across health, educational, and workplace contexts. Moreover, these experiences can mitigate feelings of imposter syndrome by validating students' abilities through tangible achievements, thereby promoting persistence in their academic and professional pursuits [11, 16].

Therefore, in this study, we propose the following research questions:

RQ1: How do structured early-stage research experiences in aerospace engineering impact URM undergraduates' self-efficacy?

RQ2: How do structured early-stage research experiences in aerospace engineering impact URM undergraduates' intention to pursue graduate education?

Mentorship, Sense of Belonging and Persistence

Social Identity Theory (SIT) is another useful theoretical framework for understanding the impact of mentorship on fostering a sense of belonging among URM students in higher education. SIT posits that individuals derive part of their self-concept from their membership in social groups, which can significantly influence their sense of belonging [17]. It also echoes the relatedness construct in SDT, in which individuals need to feel connected and have a sense of belonging with others [6].

Mentoring programs can provide a crucial support system for students, creating a supportive environment that makes it easier to overcome obstacles. Early exposure is particularly important as students can clarify their career goals, maintain engagement, and motivation towards persisting in their studies. Ultimately, organizations are thought to be able to change individual-level behaviors if modifiable factors, such as elements of one's self-identity, are affected. Therefore, it is important to consider educational settings, particularly for URM and first-generation groups who may be more likely to feel higher education is mystified.

Engagement of URM students in research projects is instrumental in fostering a strong sense of belonging within the academic community, which is a critical factor for student retention. Based on the key gist of SIT discussed above, when URM students collaborate with faculty members who are also from underrepresented groups, this shared identity can significantly enhance their connection to the academic environment and further open doors for future opportunities (e.g., increasing eligibility for scholarships or research grants, supporting conference attendance, etc.). Mentorship, particularly with mentors from similar social backgrounds, can play a crucial role in creating a powerful connection that enhances URM students' integration into the academic community [8], building professional networks. This shared identity not only provides role models with whom URM students can identify but also demonstrates that success in STEM fields is attainable for individuals from diverse backgrounds.

Based on the above discussion, we propose the following research question:

RQ3: How does mentoring impact the sense of belonging among URM students in aerospace engineering?

Research indicates that mentoring bolsters students' sense of belonging and correlate with increased persistence in STEM disciplines. For instance, a study by Kricorian et al. found that URM students who engaged in research under the guidance of faculty mentors from similar backgrounds were more likely to persist in STEM fields [8]. Research also showed that effective mentoring relationships have a positive impact on academic achievement, retention, and degree attainment, as well as career success and satisfaction, especially for students from underrepresented groups [15]. Mentoring support was to be positively associated with organizational identification and negatively associated with turnover intentions, particularly for individuals high in generativity [7]. By fostering an inclusive environment through structured, student-aligned research projects and mentorship from faculty with similar backgrounds, URM students are more integrated into the academic community.

In addition to the impact resulted from student project engagement, we will assess the role of mentorship in the development of a student's STEM identity and their sense of belonging, both of which are critical predictors of persistence and success in STEM careers. Various mentorship styles offer unique contributions that enhance persistence and success in STEM careers. For example, individualized mentorship tailors guidance to each student's strengths and challenges, while motivational mentorship addresses self-efficacy and long-term commitment by providing constructive feedback, recognizing achievements, and highlighting the broader impact of STEM research. Identity-affirming mentorship validates students' cultural backgrounds and unique perspectives, helping them view their identities as assets within STEM and building a secure

foundation for their STEM identity. Finally, resilience-building mentorship equips students with coping strategies for challenges they may face, cultivating the grit needed to persevere in a demanding field. Together, these mentorship styles holistically support URM students by fostering confidence, belonging, and resilience, ultimately promoting their retention and success in STEM disciplines.

Therefore, we propose:

RQ4: How does various styles of mentoring impact academic persistence of URM students in aerospace engineering?

Methods

Using a qualitative approach, data collection will include interviews focused on identity development, self-efficacy, and research-related motivation. Preliminary interviews conducted with URM students in both STEM and non-STEM majors by our research team revealed that self-confidence, particularly issues related to imposter syndrome, shapes students' self-assessment of their abilities [5]. STEM majors identified early exposure to STEM as a critical influence on their commitment to the fields, while non-STEM majors, such as those in communication, noted that collaborative and group-focused environments fostered a stronger sense of belonging. These findings suggest that social and cultural factors significantly influence minority students' educational paths. This study aims to provide insights into how tailored, faculty-led research experiences can cultivate belonging and resilience, ultimately enhancing retention in aerospace engineering and other STEM fields. The study protocol is under review with the Institutional Review Board, with approval anticipated in January 2025.

Specifically, we will ask the following questions:

- Can you walk me through your experience participating in the self-led research project? What tasks or activities were you involved in, and what was the overall process like for you?
- Reflecting on that experience, how has your participation in the research project influenced your understanding of your own skills? Have you discovered any new abilities, or have you become more or less confident in certain areas? How has participation in this program grow your skills?
- What barriers, if any, have you encountered?
    - Can you describe one of those barriers in more detail? How did it impact your progress or experience in the program?
    - How have you addressed or tried to overcome these barriers? Were there any specific resources, people, or strategies that were particularly helpful?
    - Were there any barriers that you felt could have been mitigated by additional support from your program or institution? What kind of support would have made a difference?
- Aside from any challenges, did you encounter any unexpected results, opportunities, or insights during your project? If so, how did these experiences influence your perspective or

approach to the project?

- How have the support systems around you, such as mentors, family, or friends, influenced your confidence in succeeding in your field?
- Which parts of this project do you think will be most valuable for your future academic or career goals?
- [As a member of an underrepresented group in the engineering field] (if applicable), how has your personal identity (e.g., background, experiences, values) influenced your sense of belonging and shaped your perspective and involvement in your field of study?
- Psychological ownership describes the extent to which individuals feel that a project or idea belongs to them. You chose you own research topic in the program. In what ways do you feel your sense of psychological ownership over your research projects has contributed to your feeling of belonging in your STEM field?
    - In what ways has having control over your research process influenced your confidence as a STEM researcher?
    - Can you explain how investing your time and effort into your research has shaped your identity as a STEM professional?
    - How has your psychological ownership of your work influenced your long-term career goals or aspirations within your STEM field?
- In the context of conducting STEM research, have you ever noticed a difference between your self-expectations and the expectations others have of you? How did you navigate this difference?
- In what ways has your mentor's experience as a woman/minority in STEM provided unique insights or support? In what ways has your mentor served as a role model for you in your STEM journey?
- Is there anything you would like to share about your experience that we have not covered?

This study is expected to provide valuable insights into the design of research experiences for URM students, emphasizing the balance between faculty guidance and student agency as a means of enhancing retention in STEM fields. Ultimately, findings will offer evidence-based recommendations for creating supportive, inclusive environments that foster URM students' persistence in aerospace engineering and beyond.

MONICA ZHAN
Dr. Zhan serves as an Associate Professor for the Department of Communication at the University of Texas at Arlington. Her research interests include employee communication and corporate communication. Recently, she has developed growing interests in underrepresented minority student and employee experiences.

GRACE BRANNON
Dr. Brannon serves as an Associate Professor for the Department of Communication at the University of Texas at Arlington.

LIWEI ZHANG
Dr. Liwei Zhang serves as an Assistant Professor in the Department of Mechanical and Aerospace Engineering at the University of Texas at Arlington. Her research interests includes fluid and combustion physics, propulsion engineering, computational science, and engineering education.

FRANK LU
Dr. Lu is a Professor in the Department of Mechanical and Aerospace Engineering at the University of Texas at Arlington. His research is in high-speed aerodynamics and propulsion, primarily in novel detonation engines.

Acknowledgement
This study was supported by the NASA M-STAR under Grant No. 80NSSC23M0208.

References

1. L. K. Alford and A. DeOrio, "Student Perceptions of Their Abilities and Learning Environment in Large Introductory Computer Programming Courses-Underrepresented Minorities," in 2019 ASEE Annual Conference & Exposition, June 2019.
2. Bandura, Self-Efficacy: The Exercise of Control, New York: W.H. Freeman and Company, 1997.
3. Bandura and D. H. Schunk, "Cultivating competence, self-efficacy, and intrinsic interest through proximal self-motivation," Journal of Personality and Social Psychology, vol. 41, no. 3, pp. 586, 1981.
4. L. Bowen, A. W. Johnson, and K. G. Powell, "Critical Analyses of Representation and Success Rates of Marginalized Undergraduate Students in Aerospace Engineering," in 2021 ASEE Virtual Annual Conference Content Access, July 2021.
5. G. E. Brannon, M. M. Zhan, K. Sakarwala, F. Lu, and L. Zhang, "Factors affecting undergraduate student degree plan choices: A qualitative study with engineering and communication students," submitted to the International Communication Association's Annual Conference, 2025.
6. E. L. Deci and R. M. Ryan, "Self-determination theory," in Handbook of Theories of Social Psychology, vol. 1, pp. 416-436, 2012.
7. M. S. Eickholt, "The effect of superiors' mentoring on subordinates' organizational identification and workplace outcomes," Master's Thesis, West Virginia University, 2018.
8. K. Kricorian, M. Seu, D. Lopez, and others, "Factors influencing participation of underrepresented students in STEM fields: Matched mentors and mindsets," International Journal of STEM Education, vol. 7, no. 16, 2020.
9. S. L. Kuchynka, A. E. Gates, and L. M. Rivera, "Identity Development during STEM Integration for Underrepresented Minority Students," Cambridge University Press, 2020.
10. R. W. Lent, S. D. Brown, and G. Hackett, "Social cognitive career theory," in Career Development and Counseling: Putting Theory and Research to Work, S. D. Brown and R. W. Lent, Eds., pp. 101-127, John Wiley & Sons, 2005.
11. J. Lindwall, "The Relationship Between Undergraduate Research Training Programs and Motivational Resources for Underrepresented Minority Students in STEM: Program Participation, Self-efficacy, a Sense of Belonging, and Academic Performance," Master's Thesis, Portland State University, 2019.
12. M. C. Linn, E. Palmer, A. Baranger, E. Gerard, and E. Stone, "Undergraduate research experiences: Impacts and opportunities," Science, vol. 347, no. 6222, pp. 1261757, 2015.
13. Lishinski, S. Narvaiz, and R. M. Rosenberg, "Self-efficacy, interest, and belongingness–URM students' momentary experiences in CS1," in Proceedings of the 2022 ACM Conference on International Computing Education Research-Volume 1, pp. 44-60, 2022.
14. K. D. Multon, S. D. Brown, and R. W. Lent, "Relation of self-efficacy beliefs to academic outcomes: A meta-analytic investigation," Journal of Counseling Psychology, vol. 38, no. 1, pp. 30, 1991.
15. National Academies of Sciences, Engineering, and Medicine, Cultivating Inclusivity: Why Mentorship Matters in Innovation and Entrepreneurship, VentureWell, 2024.
16. J. Omotade, J. King, and R. A. Kahn, "Imposter syndrome and diversity graduate students," Minority Affairs, vol. 16, no. 2, pp. 22-24, 2017.
17. H. E. Tajfel, Differentiation between social groups: Studies in the social psychology of intergroup relations, Academic Press, 1978.
18. H. Tajfel and J. C. Turner, "An Integrative Theory of Intergroup Conflict," in The Social Psychology of Intergroup Relations, W. G. Austin and S. Worchel, Eds., pp. 33-37, Monterey, CA: Brooks/Cole, 1979.
19. H. Thiry, T. J. Weston, S. L. Laursen, and A. B. Hunter, "The benefits of multi-year research experiences: Differences in novice and experienced students' reported gains from undergraduate research," CBE—Life Sciences Education, vol. 11, no. 3, pp. 260-272, 2012.
20. J. L. Smith, K. L. Lewis, L. Hawthorne, and S. D. Hodges, "When Trying Hard Isn't Natural: Women's Belonging With and Motivation for Male-Dominated STEM Fields as a Function of Effort Expenditure Concerns," Personality and Social Psychology Bulletin, vol. 39, no. 2, pp. 131-143, 2013.