Work-in-Progress: Building a Sustainability Focused Research Graduate Program for Chemical Engineering Graduate Students

Tristan Letizia, Rowan University
Rebecca Spirer, Rowan University
Dr. Andrea J Vernengo, Rowan University

Dr. Andrea Vernengo is an Associate Professor with dual appointments in the departments of chemical engineering and biomedical engineering at Rowan University. She earned her bachelor's degree from Drexel University in Philadelphia, Pennsylvania, in 2003 and completed her Ph.D. at the same institution in 2007. Her research centers on biomaterials, biofabrication, and tissue engineering, with a translational emphasis on developing cell-inspired therapeutics. She is also engaged in biomedical engineering pedagogy, integrating entrepreneurial mindset, experiential learning, and real-world problem framing into her teaching and program development.

Dr. Juan M Cruz, Rowan University

Juan M. Cruz is an assistant professor in the Experiential Engineering Education Department at Rowan University. He has a B.S. in Electronic Engineering and a Masters in Education from Universidad Javeriana in Colombia and a PhD in Engineering Education from Virginia Tech. His research uses a systems perspective to understand the dynamics of the academic system and how it influences faculty motivation to change, undergraduate students' motivation to learn, and retention and persistence of doctoral students (with special attention to underrepresented minority (URM) students).

Dr. Cheryl A Bodnar, The Ohio State University

Dr. Bodnar is a Professor in the Engineering Education Department at The Ohio State University. Her research interests relate to the incorporation of active learning techniques such as game-based learning in undergraduate classes as well as innovation and entrepreneurship.

Work-in-Progress: Building a Sustainability Focused Research Graduate Program for Chemical Engineering Graduate Students

Introduction

As modern-day research pushes more boundaries, sustainability is an important area of focus within chemical engineering research as suggested by the attendance at the 28th Annual Green Chemistry & Engineering Conference that brought "over 900 attendees from 57 countries" [1]. Not only is sustainability a growing field, but also an important one for the country and the world. The United Nations recently ratified the Agenda for Sustainable Development in 2015 which ranked the U.S. 39th out of 166 countries on goals for sustainability including areas of cleaner emissions, individual health, education, clean water, and gender equality [2]. Despite the U.S. having a strong ranking, it is still important to make intensified efforts towards the aforementioned goals relating to sustainable development as data suggests that sustainability faces a disparity between the number of individuals within the general population in the U.S who are employed or educated in sustainability fields [3,4,5]. Recent reports from the United Nations Environment Programme indicate that the world is not close to meeting the original Paris Agreement goals of 1.5C increase. To be able to meet that goal all global emissions would have to be cut by 55% by 2035 [6]. For these reasons, it is crucial for more research to be conducted within the sustainability sector to broaden awareness and encourage innovative approaches towards meeting these sustainable development goals.

The direct focus of the Rowan REACTS program is upon advancing areas of sustainability research within chemical engineering, specifically where underrepresented groups of researchers may be lacking [3-5]. Increasing this diversity of researchers within chemical engineering, and specifically in sustainability research, has the potential to encourage scientific advancement and foster innovation. Sustainability is a field of research that closely relates to women's interests, as the Economic Co-operation and Development organization found that women tend to be the ones making more consumer decisions for a household, than men [7]. It has also been observed that women tend to make more ethical consumer choices, paying more attention to issues such as child labor, sustainable livelihoods, and the use of public transportation [7]. These findings suggest that it is important to ensure that there is a supportive environment for women, but also other underrepresented groups who may make up the diverse sustainability research field.

Within engineering, graduate students from underrepresented groups do not always experience the support that they need to thrive and persist within their programs [8]. However, much work has been done in engineering to help address this gap, which may explain the increase in doctoral graduates from students of color from 13.7% in 2001 to 24.1% in 2021 [9]. Programs such as the Success for Underrepresented Students in Graduate Education (SURGE) mentoring program implemented at various universities, which worked to assist minority students in finding help with publishing articles, forming professional connections, instrumental assistance, etc. is one example of support structures now integrated within engineering. They observed that students valued the program and felt having mentors who could assist with their social capital helped to provide them with connections that would otherwise be inaccessible [10]. Another program that has shown similar benefits is the Rising Doctoral Institute (RDI), an orientation program implemented in multiple universities designed to support incoming doctoral students as they transition into graduate school. It engages a cohort of students through a structured series of workshops centered on five overarching topics for student success and opportunities for small group discussion [11].

Students from minority backgrounds often have uncertainties when arriving in a new doctoral program surrounding support structures, finding a sense of belonging, and lack of confidence in reasoning behind their hiring [12]. General attrition of engineering students before considering underrepresented groups is already low. A study conducted to analyze attrition for students beginning doctoral work in 2001 analyzed year 1 to 4 attrition rates of students and found they range from 5.2% in the first year to 21.7% in the fourth year reaching 25.4% in public institutions with private institutions having about a consistent 5% higher attrition [13]. The goal of the RDI is to benefit all students, especially underrepresented groups, thereby leading to an increase in retention rates.

Graduate Program Intervention Overview (Rowan REACTS)

Rowan REACTS supports PhD students conducting research across eight sustainability-focused areas in chemical engineering, including sustainable pharmaceutical manufacturing, data-driven healthcare systems, clean water technologies, regenerative medicine, hydrogen energy, and circular materials processing. These research themes are unified by sustainability as a defining context.

This research training is intentionally coupled with a structured teaching development pathway developed in collaboration with Rowans's Experiential Engineering Education Department (ExEEd). This collaboration resulted in the STEM Teaching Efficacy and Practice for Situated Learning Skills (STEPS) program, which provides a scaffolded, supervised teaching experience with progressive instructional responsibilities for doctoral students. PhD students begin STEPS by completing a graduate-level course offered by ExEEd on effective teaching that introduces evidence-based instructional strategies such as backward course design, active-learning techniques, and assessment of student learning. Doctoral students then participate in supervised teaching placements embedded within core chemical engineering courses, where they develop and deliver instructional modules, lead problem-solving sessions and laboratory activities, and contribute to the design and assessment of course assignments aligned with learning objectives. Teaching responsibilities are supported through structured observations, with faculty mentors attending teaching sessions to document instructional strategies, student engagement, clarity of explanation, and alignment between activities and intended outcomes. Observation results are discussed in post-observation meetings, where fellows receive actionable feedback and set targeted instructional goals for subsequent teaching assignments.

A distinctive feature of Rowan University's engineering education ecosystem is the undergraduate engineering clinic program, a multi-year, project-based curriculum recognized nationally for its impact on experiential learning. The program leverages this structure to provide doctoral students with authentic leadership and mentoring experiences. PhD students serve as co-advisors to undergraduate clinic teams, supporting project planning, technical execution, and student development. Through this experience, fellows build skills in project management, communication, and mentorship that mirror faculty and industry leadership responsibilities. By graduation, many doctoral students will have mentored dozens of undergraduate students, gaining leadership experience that is rarely formalized in traditional PhD programs. This integration also reinforces the connection between teaching and research, as clinic projects often align with the doctoral students' dissertation work.

Rowan REACTS was designed with improving doctoral persistence as a central goal. National data indicate that doctoral attrition disproportionately affects students from underrepresented groups, often due to misalignment between effort, expectations, and effective progress strategies [14]. To address this challenge, Rowan REACTS aligns with the Rising Doctoral Institute [11], a college-wide initiative launched concurrently with the first cohort of PhD students in this intervention program. The RDI provides structured workshops and peer-based community building during the critical first year of doctoral study. Workshop topics include advising and mentor–mentee relationships, program expectations and academic management, mental health and work–life balance, navigating the hidden curriculum of graduate education, building professional networks and a sense of belonging, and long-term career planning. By establishing shared expectations and early peer connections across departments, the RDI supports student preparedness for doctoral study. These structures help reduce advisor–advisee misalignment, strengthening student preparedness, and promoting timely progress toward degree completion, directly supporting the goals of the Rowan REACTs program.

Research Question:

This paper seeks to answer the following research question: *What are the baseline levels of support, identity, and persistence for students starting the Rowan REACTS graduate program?*

Methodology

This study was conducted at Rowan University which is classified as a Carnegie R2 (high research activity) institution. The university as of 2024 offers undergraduate, graduate, and professional certificate programs to about 21,125 students, of which 7,781 are part of underrepresented groups. Chemical engineering doctoral students at Rowan University in the REACTS program are the focus of the study. Six students out of the seven students within the REACTS program volunteered to participate in this survey and reflection project. The overall participant population contained 3 men and 3 women as self-identified with the survey, representing various ethnicities (Asian, African American, and White). Appropriate human subjects' approval was obtained prior to data collection.

Data Collection

Surveys were sent out to the students that consented to participate in the study. The survey used was derived from Estrada et al.'s study on social supports for graduate students within biomedical fields [15]. Specifically, the survey has questions focused upon instrumental support, psychosocial support, professional network support, friend and family support, science identity, and persistence. Questions were measured based on a Likert-Scale response. The Instrumental Support and Psychosocial Support constructs both had items measured on a scale of 1 ("Not at all satisfied") to 5 ("Extremely satisfied"). The Professional Network Support Construct had items measured on a scale from 1 ("Not at all") to 5 ("To a very large Extent") and the Friend and Family Support Construct had items measured on a scale from 1 ("Strongly Disagree") to 6 ("Strongly Agree"). The Likert Scale for the identity construct ranged from 1 ("Strongly Disagree") to 5 ("Strongly Agree") and finally the Persistence construct ranged from 0 ("Definitely will not") to 10 ("Absolutely will"). It is important to note that we modified questions on Science Identity to reflect an engineering context. An example of one of these statement modifications relating to Science

Identity is changing the prompt from "I have a strong sense of belonging to the community of scientists" to "I have a strong sense of belonging to the community of engineering".

Data Analysis

Data were analyzed using descriptive statistics (construct mean, median, and standard deviation). In order to ensure reliability of the survey elements within each construct, Cronbach's Alpha was determined using the IBM SPSS software. Values of 0.70 and above are considered reliable [16] Cronbach's Alpha for the survey constructs ranged from .57 to 1.00 where every construct except for Psychosocial was found to be at .70 or above. It is important to note that due to the small sample size (n=6) the statistical power of the analysis performed is limited and results from the Cronbach's Alpha will not carry significant meaning.

Results and Discussion

This section will summarize the results obtained from addressing the research question *What are the baseline levels of support, identity, and persistence for students starting the Rowan REACTS program?*

Overall, the data collected suggests that students' view of support within the Rowan REACTS program are overall positive at the onset of their degree (Table 1). The results specifically showcased that students felt supported through their advisors, which was assessed as part of the instrumental and psychosocial construct (construct medians of 5 for both respectively on a 5-point scale). Questions such as the ability for advisors to define goals, meet with the students, and provide feedback were all tied into the instrumental construct whereas items related to professional networking opportunities and work-life balance were found within the psychosocial construct. This is an important baseline finding since advisors have been found to serve an instrumental role in the success of PhD students within graduate programs, supporting the student's sense of belonging and motivation [17]. Also to note from the baseline findings is that students feel well supported by their friends and family. Having an external support network has been shown to be a key element in persistence within engineering programs [18].

Construct	Construct Avg based on Participant	Std.Dev of Construct	Median of Construct	Cronbach's Alpha
Instrumental	4.96	0.10	5.00	1
Psychosocial	4.79	0.33	5.00	0.566
Professional Network	4.58	0.80	5.00	0.935
Friend/Family	6.00	0.00	6.00	1
Identity	4.67	0.72	5.00	0.906
Persistence	8.00	1.43	8.50	0.711

Table 1. Student Responses to Baseline Survey Items

Identity has been shown to be an important factor in persistence and success within engineering programs [19]. Based on our results, we saw that students had very positive responses to questions about identity with minimal variability. This is an important baseline finding as it shows that

students feel they have a sense of belonging within the field and see themselves as engineers. This identity finding is also interesting as student responses suggest that they may have a slightly lower view of persistence within their related field of study (construct median of 8.50 on a 10-point scale). It is possible that the lower view of persistence has to do with the stage of their graduate training as many of the questions within this construct focused on the ability of students to continue to pursue the research they are conducting throughout their career and be able to prepare and present papers at scientific conferences. As students progress within their degree program and gain more foundational skills within sustainability research it is likely that their responses to these questions will improve. Whilst the responses are still positive, it has been found that both psychosocial and science identity experiences have significant effects on student persistence and student experiences tend to change with more time in the program [17], so monitoring how student responses to these constructs change as students progress in the Rowan REACTS program will be important.

Conclusion

The student experience with the Rowan REACTS program at Rowan University seems to be very positive in regard to the support that students have received within the first two months. They have also shown that they seem to have strong identity ties and have an overall positive perception of persistence although a bit lower than anticipated. These baseline results suggest that Rowan REACTS has provided students with sufficient support within their first months in the graduate program and have helped position the graduate students well as they get their doctoral degree underway.

Future Work

After completion of the survey, the participants were asked to complete a reflection that encouraged them to evaluate their skillsets and future areas of interest before mapping them into career pathways. This reflection followed the career exploration roadmap developed by University of California San Francisco (13) where students are given a visual aid to detail a step-by-step process to support the career exploration process. As well as providing prompts for students to detail aspirations and help guide the self-reflection process in determining future career options. Future work for this study will focus on the analysis of these career mapping reflections to understand the student career exploration process, impacts on student career choice, and experiences with engineering identity. Additionally, students will be provided with the support, identity, and persistence survey on a yearly basis throughout the Rowan REACTS program to monitor how their perception of the Rowan REACTS program changes.

Acknowledgements

Funded by U.S. Department of Education Grant No. P200A240161-25

References

[1] A. S. Cannon, D. J. Carrier, A. S. Engelberth, J. M. Garcia, E. Heath, K. Kuok (Mimi) Hii, *et al.*, "Women in green chemistry and engineering: Agents of change toward the achievement of a sustainable future," *ACS Sustainable Chemistry & Engineering*, vol. 10, no. 9, pp. 2859–2862, 2022.

[2] J. D. Sachs, G. Lafortune, G. Fuller, and E. Drumm, *Implementing the SDG stimulus*, *Sustainable Development Report*, Dublin, Ireland, 2023.

[3] National Academies of Sciences, Engineering, and Medicine, Board on Higher Education and Workforce, Committee on Strengthening Sustainability Programs, *Strengthening Sustainability Programs and Curricula at the Undergraduate and Graduate Levels*. Washington, DC, USA: National Academies Press, 2020.

[4] R. Idris, P. Govindasamy, S. Nachiappan, and J. Bacotang, "Examining moderator factors influencing students' interest in STEM careers: The role of demographic, family and gender," *International Journal of Academic Research in Progressive Education and Development*, vol. 12, no. 2, pp. 2298–2312, 2023.

[5] M. W. Asher, J. M. Harackiewicz, P. N. Beymer, C. A. Hecht, L. B. Lamont, N. M. Else-Quest, *et al.*, "Utility-value intervention promotes persistence and diversity in STEM," *Proceedings of the National Academy of Sciences*, vol. 120, no. 19, Art. no. e2300463120, 2023.

[6] United Nations Environment Programme, *Emissions Gap Report 2025: Off Track – Continued Collective Inaction Puts Global Temperature Goal at Risk*, A. Olhoff *et al.*, Eds. Nairobi, Kenya: UNEP, 2025. doi: 10.59117/20.500.11822/48854.

[7] Organisation for Economic Co-operation and Development, *Gender and Sustainable Development: Maximising the Economic, Social and Environmental Role of Women*. Paris, France: OECD Publishing, 2008. doi: 10.1787/9789264049901-en.

[8] E. Rodriguez-Mejia and C. Bodnar, "Work in progress: Designing a survey instrument to assess graduate student motivation towards degree completion," in *Proc. ASEE Annual Conf.*, Jun. 2023.

[9] L. L. Espinosa, J. M. Turk, M. Taylor, and H. M. Chessman, *Race and Ethnicity in Higher Education: A Status Report*. Washington, DC, USA: American Council on Education, 2019.

[10] M. Villarreal and N. Campbell, "Scholars from underrepresented groups in engineering and the social sciences (SURGE): Capacity in disasters and the benefits and challenges of mentoring for racial and ethnic minority graduate students," *Higher Learning Research Communications*, vol. 13, no. 1, p. 5, 2023.

[11] M. S. Artiles, J. M. Cruz, H. M. Matusovich, S. G. Adams, and G. Lee-Thomas, "The Rising Doctoral Institute: Preparing minority students for the transition into the engineering Ph.D.," in *Proc. ASEE Annual Conf. and Exposition*, 2021.

[12] M. S. Artiles, A. M. Rivera, and J. M. Cruz, "Unprepared spaces: A longitudinal examination of Black and Latiné students' first year in doctoral engineering programs," *Journal of Women and Minorities in Science and Engineering*, vol. 31, no. 5, 2025.

[13] Council of Graduate Schools, *Ph.D. Completion and Attrition: Analysis of Baseline Program Data from the Ph.D. Completion Project*. Washington, DC, USA, 2007.

[14] C. V. H.-H. Chen and C. Pfluger, "Exploring the relationship between non-cognitive and affective (NCA) factors and first-year retention of undergraduates in engineering," in *2019 IEEE Frontiers in Education Conference (FIE)*, 2019. doi: 10.1109/FIE43999.2019.9028532.

[15] M. Estrada, Q. Zhi, E. Nwankwo, and R. Gershon, "The influence of social supports on graduate student persistence in biomedical fields," *CBE—Life Sciences Education*, vol. 18, no. 3, Art. no. ar39, 2019.

[16] K. S. Taber, "The use of Cronbach's alpha when developing and reporting research instruments in science education," *Research in Science Education*, vol. 48, no. 6, pp. 1273–1296, 2018. doi: 10.1007/s11165-016-9602-2.

[17] M. S. Artiles and H. M. Matusovich, "Choosing a doctoral advisor: A study of chemical engineering students' perspectives using basic needs theory," *International Journal of Engineering Education*, vol. 38, no. 5A, pp. 1212–1222, 2022.

[18] M. S. Artiles, N. Huggins, H. M. Matusovich, and S. G. Adams, "Advisors, peers, and counterspaces: The socialization of minoritized doctoral engineering students," *Journal of Diversity in Higher Education*, vol. 18, no. 6, pp. 972–987, 2025. doi: 10.1037/dhe0000628.

[19] C. G. P. Berdanier, C. Whitehair, A. Kirn, and D. Satterfield, "Analysis of social media forums to elicit narratives of graduate engineering student attrition," *Journal of Engineering Education*, vol. 109, no. 1, pp. 125–147, 2020. doi: 10.1002/jee.20299.

[20] UCSF Office of Career and Professional Development, "MIND materials," University of California, San Francisco. [Online]. Available: https://career.ucsf.edu/phds/career-exploration/MIND/materials