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Engineering and Science Student Preparedness for Research: Exploring the Connections Between Student Identity and Readiness for Research

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Abstract

It has been suggested that engineering research is advanced by an increasingly diverse population of Science, Technology, Engineering, and Mathematics (STEM) researchers with interdisciplinary research objectives. To develop a diverse population of STEM researchers, we must understand how their identities influence their feelings of preparedness for research experiences. The purpose of this study was to understand how a student's perception of preparedness is influenced by the student's science and engineering identity and his/her participation in interdisciplinary research. Underrepresented minority science and engineering undergraduate students participated in a National Science Foundation: Emerging Frontiers in Research and Innovation – Research Experience and Mentoring (REM) program for 1 semester. At the end of this research experience, students (n=10) were given an identity "pre-survey". A follow-up identity "post-survey" was given the first week of fall semester following various summer activities in which students participated. Domain-specific interest survey items revealed significant differences between science and engineering majors when the topic was engineering, for both pre-survey and post-survey responses. Results also indicate that both engineering and science majors are relatively confident in their level of preparedness for future research, signified by means above 6.0 for nearly every preparedness item. Before the summer experience, science students perceived significantly higher ($p = 0.0039$) recognition from their mentor(s) as compared to engineering students, whereas in every other aspect of science identity there were no significant differences by major in either pre- or post-summer experience items. The results suggest that early-stage engineering students identify less with research compared to their science counterparts and, subsequently, feel less prepared to conduct research; however, participation in an interdisciplinary experience increases their indication of academic research preparedness. The results show for, the population studied, that participation in a research program, such as REM and summer Research Experiences for Undergraduates, increases minority students' research identity, which may assist in increasing diversity of the STEM research population.

Introduction

The increasingly technical global economy and rapidly changing national demographics have presented the US with a critical workforce shortage in the educational areas of Science, Technology, Engineering, and Mathematics (STEM).[1] As the country attempts to maintain its leadership position in research, development, and innovation, studies reported in the literature have made clear that US production of STEM graduates needs improvement. Employment in STEM fields grew by 23% between 1994 and 2003, compared to only 17% for non-STEM fields; nonetheless, the US is now struggling to meet the rapidly increasing demand for STEM workers.[2] The continued need to remain globally competitive and the fact that 39% of people in the US under 18 are persons of color (U.S. Census 2000) underlie the urgent need for colleges and universities to improve their efforts to graduate minority students in STEM disciplines.[3]

Along with an increased interest in undergraduate degree attainment, there is significant interest in increasing the number of graduate degrees awarded in STEM, particularly to underrepresented minority students.[4] STEM education researchers have commonly defined underrepresented minorities (URMs) as African American, Hispanic/Latino, or Native people, including Native American, Alaska Native, Native Hawaiian, and Pacific Island individuals.[4] The drive to increase the number of graduate degree recipients is directly relevant to research and innovation goals and national economic interest.[4] One of the strategies employed for increasing the number of URM students in STEM has been the introduction and promotion of undergraduate research programs. Both federal and private agencies have committed to investing significant funding into these programs, as they have been reported to increase student intention of enrolling in graduate or professional schools.[5,6]

Many researchers have explored potential causes for minority student underrepresentation in the STEM disciplines. Issues such as preparedness deficiencies, stereotype threats, familial or societal expectations, or low esteem have been presented as potential reasons for low interest, aspiration, admission, retention, and persistence in STEM of ethnic minority students.[7-14] Diminished pursuit of graduate studies for URM students were thought to be largely related to financial hardship post baccalaureate; however, further research has shown that URMs in STEM also may not see graduate or professional schools as significantly beneficial to career aspirations and interest.[15]

Undergraduate research programs have been shown to be effective in fostering the interest, skills, and aspirations that may develop into pursuit of graduate/professional school and potential research and innovation careers.[5,6] The concept of "communities of practice" described by Wenger supports the idea that participation in different communities and experiences affects participant identity development.[16] The National Science Board members, in their report "Moving Forward to Improve Engineering Education", propose participation in research experiences, specifically in the freshman and sophomore years, as a desirable means to engage URM students in the community of STEM.[17] These experiences aim at introducing students to STEM and broadening their education while improving retention. One aspect that has been highlighted by undergraduate research experts is identity development within the context of STEM.[5] Attention to identity has increased, specifically within the sciences,[18] as work continues toward increasing the STEM population and workforce. Investigators have suggested that participation in an undergraduate research program results in domain identity related to the area of participation.[19] It is this identity development process that fosters feelings of preparedness for future research and creation of a research identity integrated with a student's STEM domain-specific identity. Domain-specific identity, comprising three dimensions of student beliefs - interest, performance/competence, and recognition, has been used to observe math, physics, and general sciences identities.[20-25]

It has been suggested that engineering research is advanced by an increasingly diverse population of STEM researchers aiming to accomplish interdisciplinary research objectives. Diversity of thought and perspective is a prerequisite to addressing the world's complex problems. There is a significant need for training and development of diverse populations to answer evolving research questions. To develop researchers one must understand how their identity, which is based on a researcher's belief about his/her performance, competence, recognition by others, and interest, influences their feelings of preparedness for research experiences. It is our assertion that students that feel more prepared for research experiences are more likely to participate in future research experiences. Our study focused specifically on a research training opportunity funded by the National Science Foundation (NSF) Emerging Frontiers in Research and Innovation (EFRI) program. Student experiences highlighted in this study pertain to their participation in an NSF-EFRI Research Experience and Mentoring (REM) program during the academic year and subsequent research or professional experiences the following summer. These research or professional experiences included Research Experience for Undergraduates (REU) programs, cooperative education (co-op) experiences, institutionally-funded research programs, and other summer employment opportunities. The purpose of this study was to understand how a student's perception of preparedness is influenced by the student's science and engineering identity, based on their participation in interdisciplinary research.

Methods

Clemson University (CU) and the University of North Carolina at Charlotte (UNCC) receive NSF:EFRI funds that allow CU engineering researchers and UNCC biology researchers to work together to build and analyze breast cancer benchtop tissue test systems. The NSF distributed a competitive call for supplemental funding proposals to funded EFRI grantees, termed Research Experience and Mentoring; the goal of the opportunity was to further the progress in EFRI topic areas while broadening participation of underrepresented groups in STEM fields.[26] CU and UNCC successfully competed and were awarded REM funding for the 2012-2013 academic year. The objective of the CU-UNCC NSF:EFRI-REM program was to introduce URM undergraduate students, especially those at an early transition point in their academic career, to a positive introductory research experience that would inspire confidence and create credentials for future research opportunities. Students with no prior research experience were specifically sought. Each student participated in 1 semester of the NSF:EFRI-REM program, either in the fall or spring, and each had the opportunity to apply to participate in a 10-week REU program encompassing experiences at both universities. All REM participants were encouraged to apply for other REU programs across the nation, other summer research experiences, or co-operative education experiences.

During the school year, URM students were recruited through CU and UNCC-supported offices with focus on underrepresented student recruitment and retention in STEM. Students were encouraged to apply for the REM opportunities and were selected based on their interest in the program, their ability to communicate how this experience might influence them, and their academic progress (including performance in STEM classes). The principal investigators, graduate student and staff mentors reviewed applications, and the undergraduate students, termed by NSF the Research Participants (RPs), were invited to participate in the REM program. Each semester, the REM program began with a Research Studio lasting approximately 8 hours before students began the laboratory experience. The Research Studio included an introduction of tissue test systems and overall EFRI project goals, completion of laboratory safety training, an introduction to research ethics, technical writing, and basic laboratory practices, participation in a team building exercise, discussion of the projects to which each student would be exposed, and discussion of the expectations for and of RPs. Once RPs completed the Research Studio, each RP was paired with a graduate student mentor and the mentor's project. After completion of the Research Studio, each student was required to spend 3 hours on lab/research-related activities each week during the semester. Weekly professional development exercises introduced the RPs to a variety of research-related skills and topics. Students ended the semester with a rapid fire podium presentation and poster presentation at Networking Day, a day where all students, graduate student mentors, faculty mentors, and external support mentors gathered to discuss research activities and outcomes of the REM program.

The joint EFRI:REU began in late May for a 10-week period and included two RPs from CU and two RPs from UNCC. The first 5 weeks were spent in the engineering laboratories at Clemson University, and the second 5 weeks in cancer biology laboratories at the University of North Carolina at Charlotte. Each REU weekday consisted of approximately 8 hours of lab/research-related activities. All EFRI:REU RPs gave poster presentations overviewing their research at the end of the REU and all EFRI:REU students were invited to apply to participate in/present at the NSF and American Association for the Advancement of Science-sponsored Emerging Researchers National Conference in STEM in Spring 2014.

Each academic semester, eight RPs participated in the REM program, four at each university. The demographics of the population were determined by information submitted in the REM applications, including gender, ethnicity, college level, major (with concentration), and minor. Of the 16 RPs in the REM program, three were male and thirteen female. Students self-indicated their ethnicity on the application as: Hispanic or Latino (regardless of race), American Indian or Alaska Native, Asian American, Black or African American, White, or Native Hawaiian or Other Pacific Islander. The population included two Hispanic or Latino students, thirteen Black or African American students, and one Asian American student. RPs included thirteen sophomores, one freshman, and two juniors. Clemson University RPs were students seeking either engineering or science degrees while University of North Carolina at Charlotte RPs were students pursuing science degrees. Out of the 16 participants, six were obtaining engineering degrees in industrial engineering, computer engineering, environmental engineering, and chemical engineering, while two had yet to declare an area of focus and were still in the general engineering program. The other 10 students were pursuing science degrees; specifically, chemistry (1) and biology (9). Of the 16 students that participated in the REM program, two from each university were selected to participate in the summer REU program. All of the REU participants were female and three of the four were science majors. The REU RPs identified their ethnicities as Asian American (1), Hispanic/Latino (1), and Black or African American (2).

An identity survey was used in order to assess identity development after participation in the REM program. Former REM RPs were given an identity pre-survey in May before they started their summer activities. Eleven of the 16 participants completed the pre-survey. Students that completed the pre-survey were given a follow-up identity post-survey the first week of the fall semester following the various summer activities. Ten post-surveys were completed; five by science majors and five by engineering majors. The summer experiences of these 10 RPs included REU (4), co-operative education experience (2), summer research experience (2), and non-research related activities (2). The identity survey questions were adapted from the Sustainability and Gender in Engineering (SaGE) survey.[20-22,24,25] Questions for engineering and research identity were adapted from these valid and reliable survey items with the help of experts in engineering education research. The survey items were divided into three identities; science, engineering, and scientific research. The same questions were asked to investigate each identity, substituting the word science, engineering, or scientific research in each item. Each question was evaluated on a Likert-type scale, the far left of the scale anchored as "Strongly Disagree" (1.0) and the far right of the scale anchored as "Strongly Agree" (7.0). Questions in the survey pertaining to preparation were categorized based on the type of future experience, and included research, non-research, and graduate research questions. Statistical analysis of the data was conducted using Analysis of Variance (ANOVA, $p<0.05$) to determine statistical differences between majors, for both pre-survey and post-survey responses, and within majors (pre- to post-response).

Results and Discussion

Results from pre- and post-surveys suggest that science and engineering identities are related to each other, as well as to the development of research identity. The analyses shown below in Tables 1, 2, and 3 compare survey item responses for science majors versus those of engineering majors. For example, the first line of Table 1 indicates that pre-survey responses for science majors yielded a mean (μ) response of 6.80, while engineering majors had a mean response of 7.0. These responses were related to the question, "To what extent do you disagree or agree with the following statement? I am interested in learning more about science." The difference in science majors' and engineering majors' pre-responses yielded a non-significant p-value of 0.3466 after ANOVA testing. Similarly, post-responses also had a non-significant difference (p-value = 0.1720) with means of 7.0 and 6.4 for science and engineering, respectively. Analyses completed comparing pre- to post-responses within majors were conducted but are not included in table format. Only two of the survey items were significant; descriptions of these items are included below.

Table 1: Self-Reported Interest Items Comparing Science and Engineering Majors. Symbols μ and σ represent the mean and standard deviation of the population, respectively. P-Values highlighted indicate significant differences between majors.

	Pre-Summer Experience					Post-Summer Experience				
	Sci.		Eng.		P-Value	Sci.		Eng.		P-Value
Survey Item	μ	σ	μ	σ		μ	σ	μ	σ	
To what extent do you disagree or agree with the following statements?										
I am interested in learning more about science	6.80	0.45	7.00	0.00	0.3466	7.00	0.00	6.40	0.89	0.1720
I enjoy learning science	7.00	0.00	6.60	0.55	0.1411	6.80	0.45	6.60	0.55	0.5447
To what extent do you disagree or agree with the following statements?										
I am interested in learning more about engineering	5.00	1.73	7.00	0.00	0.0325	5.20	1.64	6.80	0.45	0.0688
I enjoy learning engineering	4.40	0.89	6.80	0.45	0.0007	5.20	0.84	6.80	0.45	0.0055
To what extent do you disagree or agree with the following statements?										
I am interested in learning more about scientific research	6.60	0.55	6.40	0.89	0.6811	6.75	0.50	6.40	0.89	0.5097
I enjoy learning scientific research	6.60	0.55	6.40	0.89	0.6811	6.60	0.55	6.40	0.89	0.6811

Two questions addressed the aspect of domain-specific interest. The questions "I am more interested in learning more about …" and "I enjoy learning …" revealed significant differences between the science and engineering majors when the topic was engineering, for both the pre-survey and post-survey responses (Table 1). While the science and engineering majors' means for both the pre-survey and post-survey are nearly equal for science and scientific research identity items, the engineering identity items reveal a significant difference. Engineering students identified much more interest in engineering topics as compared to the science students.

Questions were posed about RP competence in the three areas of science, engineering, and research. While the survey items addressed competence, performance was not included in this analysis as there were no grades assigned to student research outcomes. Regarding competence (Table 2), it was found that science students felt significantly less confident in their ability to understand science outside the classroom after their summer experience. This could be, in part, because more in-depth research and summer experiences broadened the students' perspectives to what is required to understand science and conduct scientific endeavors outside the classroom.

The other area of significance of note within competence from Table 2 is in the differences of "understanding engineering", "understanding concepts studied in engineering", and "being able to overcome limitations and setback/obstacles in engineering". Significant differences were seen by science students in all of these categories except "I am confident that I can understand engineering in the laboratory". The results may be explained, in part, by the fact that three of the five science majors who completed the surveys participated in the joint summer EFRI:REU program. The summer EFRI:REU incorporated an engineering component and thus many of the science majors were exposed to engineering problems. The engineering students were significantly more confident in every one of these categories after their summer experiences. This result was expected, as all but one of the engineering RPs that completed the survey were involved in summer research that focused on some aspect of engineering, most of them in areas of their own majors. These RPs gained experience and knowledge in their specific engineering areas and thus would have strengthened identity in the area of competence. The engineering question that did not result in significant differences when comparing majors both pre- and post-summer experience was "Engineering makes me nervous". However, the science students, when comparing their pre- to post-summer experience responses with respect to science, did indicate significantly less ($p = 0.0046$, data not shown in table format) nervousness post-summer.

One of the major foci for this study was the development of feelings of preparedness for future research opportunities. Results shown in Table 2 below indicate that both engineering and science majors are relatively confident in their level of preparedness for future research. This is signified by means above 6.0 for nearly every preparedness item. There was no significant difference between engineering and science majors in terms of preparedness, suggesting the program helped to develop confidence in research preparedness across the spectrum of represented majors. The mean confidence level of science majors with respect to preparedness items was also slightly higher (though not significant), again indicating that perceived research outcomes may be more closely related to the skillset students identify with science.

Table 2: Self-Reported Competence Items Comparing Science and Engineering Majors. Symbols μ and σ represent the mean and standard deviation of the population, respectively. P-Values highlighted indicate significant differences between majors.

	Pre-Summer Experience					Post-Summer Experience				
	Sci.		Eng.		P-Value	Sci.		Eng.		P-Value
Survey Item	μ	σ	μ	σ		μ	σ	μ	σ	
To what extent do you disagree or agree with the following statements?										
I am confident that I can understand science in class	6.40	0.55	6.20	0.84	0.6666	6.80	0.45	6.80	0.45	1.0000
I am confident that I can understand science in the laboratory	6.20	0.45	6.20	0.84	1.0000	6.60	0.55	6.20	1.10	0.4860
I am confident that I can understand science outside of class	6.40	0.55	5.20	0.84	0.0278	6.60	0.55	6.40	0.89	0.6811
I understand concepts I have studied in science	6.60	0.55	5.80	0.84	0.1114	6.80	0.45	6.60	0.55	0.5447
Science makes me nervous	4.20	1.79	3.20	2.28	0.4626	3.20	1.48	3.40	2.07	0.8651
I can overcome limitations in science	5.60	0.89	5.75	1.50	0.8565	6.20	0.84	6.40	0.55	0.6666
I can overcome setbacks/obstacles in science	5.60	0.89	6.00	1.00	0.5237	6.40	0.55	6.40	0.55	1.0000
To what extent do you disagree or agree with the following statements?										
I am confident that I can understand engineering in class	4.40	0.55	6.40	0.55	0.0004	4.80	1.48	6.40	0.89	0.0727
I am confident that I can understand engineering in the laboratory	5.20	1.30	6.40	0.55	0.0943	5.20	1.64	6.00	1.00	0.3796
I am confident that I can understand engineering outside of class	4.40	0.89	6.00	0.00	0.0039	4.60	1.52	6.40	0.89	0.0516
I understand concepts I have studied in engineering	4.40	0.89	6.40	0.55	0.0027	4.40	1.82	6.20	0.84	0.0790
Engineering makes me nervous	4.60	0.89	3.60	2.30	0.3917	3.00	1.22	3.00	1.41	1.0000
I can overcome limitations in engineering	4.00	0.71	6.00	1.00	0.0065	4.20	0.45	6.40	0.55	0.0001
I can overcome setbacks/obstacles in engineering	4.00	0.71	6.20	1.10	0.0054	4.60	0.89	6.40	0.55	0.0050
To what extent do you disagree or agree with the following statements?										
I am confident that I can understand scientific research in class	6.40	0.55	5.80	0.45	0.0943	6.60	0.55	6.20	0.84	0.3972
I am confident that I can understand scientific research in the laboratory	6.40	0.55	6.00	0.00	0.1411	6.60	0.55	6.20	0.84	0.3972
I am confident that I can understand scientific research outside of class	6.00	0.71	5.60	0.55	0.3466	6.40	0.55	6.00	1.00	0.4554
I understand concepts I have studied in scientific research	6.20	0.45	5.80	1.10	0.4714	6.60	0.55	5.80	0.84	0.1114
Scientific research makes me nervous	4.80	1.30	4.00	2.00	0.4751	3.40	1.52	3.40	1.82	1.0000

I can overcome limitations in scientific research	5.80	0.45	6.00	1.22	0.7404	6.20	0.84	6.40	0.55	0.6666
I can overcome setbacks/obstacles in scientific research	5.80	0.45	6.40	0.55	0.0943	6.40	0.55	6.40	0.55	1.0000
To what extent do you disagree or agree with the following statements? I feel prepared to participate in...										
Academic research program (e.g. REU, research experience) offered during the summer	6.40	0.55	6.00	0.71	0.3466	6.80	0.45	6.40	0.89	0.3972
Academic research programs offered during the academic year	6.40	0.55	6.20	0.45	0.5447	6.80	0.45	6.60	0.55	0.5447
Non-academic research program (e.g. scientific or engineering based co-operative education experience or internship) offered during the summer	6.20	0.45	6.40	0.55	0.5447	6.60	0.55	6.40	0.89	0.6811
Non-academic research programs offered during the academic year	6.20	0.45	6.20	0.45	1.0000	6.40	0.55	6.20	0.84	0.6666
Continued research at the graduate level	6.40	0.55	5.75	0.96	0.2381	6.40	0.55	5.80	1.10	0.3052

The third aspect of identity, recognition, reveals some of the stark differences between science students and engineering students with respect to how they and others recognize them in the communities of practice of science, engineering, and research. Recognition plays a crucial role in how people see themselves fitting into a Community of Practice and a lack of recognition has been shown to deter students from pursuing certain career paths.[27]

Before the summer experience, science students reported significantly higher ($p = 0.0039$) recognition from their mentor(s) as compared to engineering students, whereas in every other aspect of science identity (i.e. recognition of self and recognition by parents, friends, advisor(s), and faculty), there were no significant differences by major in either the pre- or post-summer experience items. Engineering identity of science majors was significantly lower (Table 3) compared to the engineering majors both pre- and post-summer experience, except for recognition by their mentor(s) in the pre-survey. The higher recognition by mentor(s) of the science students in this category could be due to the fact that two of the five science students who completed the surveys participated in the engineering REM program instead of the science REM program, thus their mentor(s) were of engineering backgrounds instead of biology. The last significant difference of note was between majors evaluating the survey item “Others ask me for help in scientific research”. The science student responses, in the pre-survey, reveal significantly higher ($p = 0.0438$) recognition with respect to others asking their help compared to engineering majors. This difference is most likely influenced by the coursework completed by each student. Many of the engineering students, at this point in their degree progress, have just begun to enroll in science-related classes, whereas science degree-seeking students enrolled in general science classes immediately upon matriculation as they are required to take many more science classes compared to engineering students. Further, engineering students are less likely to take a biology class compared to science students, as most engineering degrees require many more physics classes and physics is not, at this point, classified as a general science class for engineering majors.

Table 3: Self-Reported Recognition Items Comparing Science and Engineering Majors. Symbols μ and σ represent the mean and standard deviation of the population, respectively. P-Values highlighted indicate significant differences between majors.

	Pre-Summer Experience					Post-Summer Experience				
	Sci.		Eng.		P-Value	Sci.		Eng.		P-Value
Survey Item	μ	σ	μ	σ		μ	σ	μ	σ	
To what extent do you disagree or agree with the following statements?										
I see myself as a science person	6.60	0.55	5.80	1.10	0.1823	7.00	0.00	5.60	2.19	0.1909
My parents see me as a science person	6.60	0.55	5.80	1.64	0.3319	6.80	0.45	5.60	2.07	0.2415
My friends see me as a science person	6.80	0.45	5.40	1.34	0.0578	7.00	0.00	5.40	2.07	0.1228
My faculty advisor sees me as a science person	6.20	1.30	5.40	0.89	0.2907	6.80	0.45	4.75	2.06	0.0641
My mentor(s) see me as a science person	6.60	0.55	5.00	0.71	**0.0039**	6.80	0.45	5.40	2.07	0.1783
My professor(s) see me as a science person	6.00	1.22	4.80	0.45	0.0736	7.00	0.00	5.20	2.05	0.0851
Others ask me for help in science	6.00	0.71	5.20	1.48	0.3080	6.40	0.89	6.40	0.89	1.0000
To what extent do you disagree or agree with the following statements?										
I see myself as an engineering person	3.80	1.64	6.60	0.55	**0.0068**	4.20	1.64	6.60	0.55	**0.0147**
My parents see me as an engineering person	2.80	1.10	6.40	0.55	**0.0002**	3.80	1.30	6.40	0.55	**0.0034**
My friends see me as an engineering person	2.75	1.50	6.20	0.84	**0.0031**	3.60	1.52	6.40	0.55	**0.0047**
My faculty advisor sees me as an engineering person	2.40	1.14	5.80	0.45	**0.0003**	3.40	1.34	6.40	0.55	**0.0017**
My mentor(s) see me as an engineering person	3.80	2.17	5.80	0.45	0.0780	4.00	1.58	6.40	0.55	**0.0125**
My professor(s) see me as an engineering person	3.20	1.64	5.40	0.55	**0.0218**	3.40	1.34	6.20	0.84	**0.0042**
Others ask me for help in engineering	3.00	1.22	6.00	1.00	**0.0028**	2.20	1.30	5.80	1.64	**0.0050**
To what extent do you disagree or agree with the following statements?										
I see myself as a scientific research person	5.80	0.45	5.40	1.52	0.5871	6.60	0.55	5.20	2.05	0.1783
My parents see me as a scientific research person	6.20	0.45	5.20	1.48	0.1869	6.00	0.71	5.40	1.95	0.5358
My friends see me as a scientific research person	6.40	0.55	5.20	1.48	0.1281	6.60	0.55	5.20	1.92	0.1562
My faculty advisor sees me as a scientific research person	6.00	0.00	5.20	1.30	0.2073	6.20	0.45	5.00	2.12	0.2509
My mentor(s) see me as a scientific research person	6.20	0.45	5.20	1.30	0.1434	6.60	0.55	5.20	2.05	0.1783
My professor(s) see me as a scientific researcher	5.80	0.45	4.80	1.30	0.1434	5.80	1.30	5.40	2.07	0.7245
Others ask me for help in scientific research	5.00	1.00	3.00	1.58	**0.0438**	5.60	0.55	5.00	1.87	0.5108

One of the major outcomes of this analysis was the indication that science RPs did not identify as engineers, either before or after participation in various summer experiences. This result was consistent across all explored aspects of identity: interest, competence, and recognition. This result was also statistically significant across most survey items concerning engineering identity, with science RPs reporting statistically lower means than those of their engineering RP counterparts. For the RPs surveyed, this result suggests a distinction between science and engineering for students majoring in science. When comparing science major responses with regard to science identity to corresponding engineering identity items, a significantly higher mean response (statistics not shown in table) can be seen for science responses. This further supports the assertion that these science RPs have very strong viewpoints on the components of science identity and its distinction from engineering identity components.

In contrast to these results, engineering RPs indicated comparable levels of science identity as reported by their science RP colleagues. It can be seen across each measured component of identity that engineering student and science student responses to science-focused identity items resulted in non-significant differences in most cases. It is our assertion that these results indicate an intersectionality of science identity and engineering identity for engineering students. These students do not see the two fields of study as inherently different as do the science students. This idea is supported by the work of Godwin and coworkers, in which both science and physics identities were shown to support or contribute to the development of engineering identity.[22] These results suggest that for these engineering students, the components contributing to a strong science identity are the same as, or necessary for the development of, the components of their engineering identities.

These contrasting results are interesting, considering the implications derived from the research identity items explored in this study. For the most part, research identity items yielded non-significant differences between science and engineering majors for both pre- and post-survey results. However, closer examination of the mean values of these items reveal that, although not significant, science majors consistently reported slightly higher responses than engineering majors with respect to research identity items. Because these results are not statistically significant and because of the limited sample size, one cannot definitively conclude science majors report higher research identity than engineering majors. However, the consistency of the responses across all areas of identity suggests that science identity may be more closely linked to research identity for these students. Interestingly, the lack of significant difference also suggests that engineering students also readily identify with components of research. Two explanations may clarify this result. First, engineering students may identify with research through some set of components common to both engineering and science identity. This explanation supports the previous assertion there is significant intersectionality between the science and engineering identities of engineering students. Second, engineering students may identify with research through their identification with science. This idea supports the previous statement that the most direct link to research identity may be through a strong science identity, but science and engineering identities are indeed separate. Figure 1 below illustrates these two potential explanations.

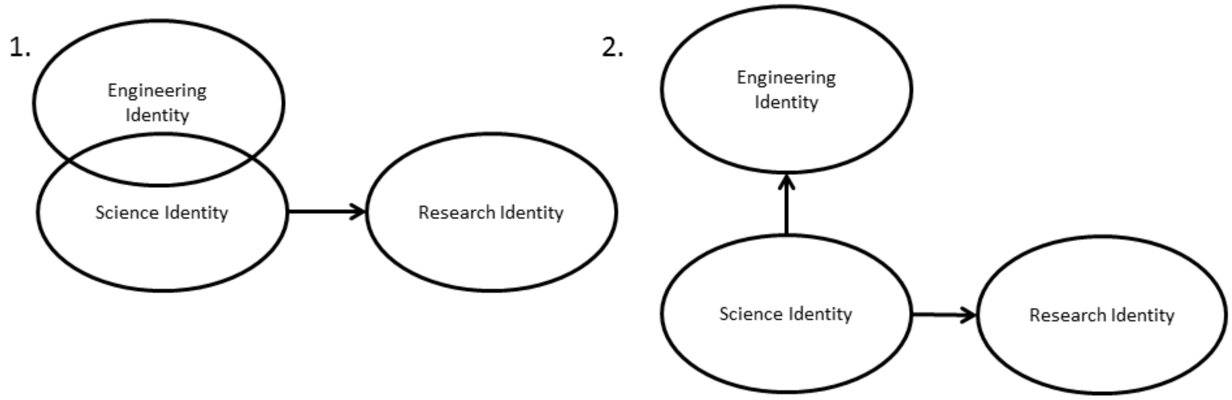

Figure 1: Potential explanations for research identity data. 1) Significant intersectionality between engineering and science identities, with science identity being most directly linked to research identity. 2) Engineering and science identity are distinctly different, but connected. Science identity is most directly linked to research identity.

It is also important to note some outcomes of this work not specifically related to the analysis. Science student post-survey results indicated a significantly higher response to the item, "I see myself as a research person" when compared to pre-survey results. This result indicates a significant growth in the self-recognition component of research identity for this group of students. It was the goal of this work to improve research identity development in these students; therefore, this result was a positive outcome of the study. Corresponding engineering student results for this item indicate comparable pre- and post-results without a statistically significant difference. This result reinforces the previous assertion that students of both majors more closely associate research with science at this stage in their academic development. It is our hypothesis that the differing natures of summer experiences for the engineering students responding to this survey may have played a role in research identity indication. We also hypothesize that students overwhelmingly consider research to be an academic exercise; therefore, students participating in more industry-focused experiences may not have associated their specific summer activities with research.

The results suggest that engineering students identify less with research, as compared to science students, and subsequently feel less prepared to conduct research; however, participation in an interdisciplinary experience increases their indication of academic research preparedness. The results show, for the population studied, that participation in a research program, such as REM and summer REUs, increases URM student research identity which, in turn, could help increase diversity of the research population.

Limitations and Future Directions

While this work is a good starting point to better understand minority undergraduate students' perceptions of science, engineering and research identity and preparedness to conduct research, it is evident that the program, and therefore the survey, is limited by the small sample size. While this study was intended to assess how students participating in the program identify within science, engineering, and research, further, in depth work assessing engineering and research identity is necessary to better understand how federally-funded and related programs impact students and the future of STEM fields. Some limitations of the study related to the survey items include the adaptation of items and missing data. The survey items have been validated and proven reliable for science and math identity through the SaGE study.[25] Further, missing data responses were dealt with by deleting entire responses for missing pre- or post- results.

Future work in this area of study should focus on capturing a larger, more representative population of undergraduate researchers. A longitudinal study would be insightful to follow up this work in order to see how the identities of science, math, engineering, and research change and morph over time with each RP's experiences and beyond, as he/she becomes part of the STEM community. Future work comparing research experiences of URMs to those of non-URM students would add insight regarding the relationship between ethnicity, gender, or experience level and research identity, or regarding the influence of cultural differences (e.g. between English speaking countries, other Western countries, and Eastern European or Asian or African countries) on identity development. Further work must be conducted to establish the validity and reliability of research identity survey items. Based on current literature, science, math, and physics identities factor into the development of engineering identity.[22] Future research may explore the relationship of these already validated identities with research identity, or may explore the connection of engineering identity to research identity.

Conclusions

The overall motivation for this work is to increase the number of underrepresented minority students pursuing STEM careers which may lead to the fulfillment of research and innovation goals for the United States in years to come. It is our position that participation in undergraduate research programs foster the development of research identity in both science and engineering students and will allow students to feel more prepared to pursue further research opportunities. The program highlighted in this work combined "hands-on" experience with faculty and graduate student mentoring to develop this research identity. Interest, competence, and recognition are critical factors in the development of any type of identity. Survey tools used in this study sought to explore the effect of participation in this program on those factors in identity development. Results showed that science students and engineering students may see their respective areas of study in different lights than their counterparts, but also they see research and its connection to their established academic identities as different. Science majors seemed to identify highly with only science, while engineering students identified with both science and engineering identity items. Science identity seemed to be the most direct link to the development of research identity in these students. Based on the results from this study, we consider these programs to be a positive and impactful experience for underrepresented minority students interested in research careers.

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