The Shift from the Two- to Four-Year Institute: How Research Experiences Impact Community College Students

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Introduction

Research is messy and ill-defined. It provides society with new ideas, innovations, and challenges. Undergraduate research is a project-based learning experience with little structure or guidelines. It can be overwhelming and intimidating to a student. Typical classroom work consists of textbook-based homework assignments or projects with rubrics, guidelines, and straight forward problems leading to a single solution. In research experiences, students are posed a problem and expected to find the answer with minimal experience of problem-solving. These beneficial experiences provide students with a glimpse into real-life problems in engineering and help to develop the skills required to work in engineering today.

At most four-year institutions, research experiences are common, with some universities hosting numerous types of research experiences for students. However, at two-year colleges, they are virtually non-existent. Research experiences can provide vast benefits such as understanding their major discipline, obtaining critical thinking skills, improving their communication skills, gaining networking opportunities, and increasing the probability of pursuing graduate education [1]. Also, research experiences can provide increased self-efficacy. Due to the lack of opportunities at a two-year institution, a Research Experience for Undergraduates (REU) Program purposefully recruited from a local community college. By recruiting from community college students, we provide opportunities to underrepresented populations, women, and others which can meet the demand for science, technology, engineering and mathematics (STEM) graduates for the United States to remain globally competitive [2].

As global competitiveness increases, community colleges can also help to increase interest in STEM careers, especially engineering. Through research experiences, community college students are provided new opportunities and experiences that are typically not offered at a two-year institution. It also increases community college students' interest in engineering and self-efficacy with the benefits of technical experiences.

REU Program

The REU Program is part of a joint Education and Workforce Program at North Carolina State University's Future Renewable Electric Energy and Delivery Management (FREEDM) Systems Center and PowerAmerica Institute. The FREEDM System Center is a National Science Foundation funded Engineering Research Center approaching their eleventh year. Their research focuses on modernizing the electric grid with focuses in electric vehicles, the smart grid, and the solid-state transformer. Wide bandgap (WBG) semiconductor technology was researched and utilized at FREEDM Systems Center in which it was then proposed as the focus of a Manufacturing USA Institute. In 2015, PowerAmerica Institute became part of the fourteen Manufacturing USA Institutes in which it is funded through the Department of Energy. Their contribution to an emerging technology like WBG is significant and innovative. Due to the need

for a demanding workforce, the REU Program is an outlet for recruitment into these emerging technologies as well as an opportunity to increase diversity in the field.

During the ten-week duration of the REU program, students were immersed in research as they developed their professional and technical skills. The key purpose of this NSF-funded program was to increase interest to attend graduate school after degree completion. REU participants were matched with a Principal Investigator (PI), Graduate Mentor, and a project. The Graduate Mentor worked closely with the student by providing deadlines and expectations from the research project.

The Education and Workforce team led students in weekly sessions, such as technical writing, conducting a perfect pitch, writing a literature review, and presenting a research poster. In addition, two electrical engineering Ph.D. students led weekly technical labs and seminars on skills needed in engineering, such as SolidWorks, systems-level electronics, and Arduino. This enabled equal opportunity for students to develop their background knowledge to be successful in research and be prepared for the workforce. Students were provided a variety of experiences in which they applied their skills in a real-life context as well as developed personally. There were bi-weekly field trips to various companies as well as to local museums. Students not only grew professionally but personally to be more relatable in networking situations. Professionally, students attended conferences and summer workshops where they had the opportunity to interact with academia and industry. The weekly sessions and deliverables from the program were:

- Webinars: Industry representatives, the Diversity Director, Graduate School, and faculty shared their expertise and specialty with an informative and engaging presentation. Students were given insight on various career pathways, graduate application strategies, and professional skills.
- Lectures: A doctoral student shared background information, the latest research, and trends in the field as well as different sessions on professional skills such as resume-building and applying for graduate school.
- Labs: The summer research students participated in technical courses that covered the following topics: fundamentals of scientific research, MATLAB programming, electric circuit design/topologies, electric vehicles, Arduino programming, and WBG semiconductors. The purpose of these courses was to expand upon the topics that the students are exposed to in their courses and summer research.
- REU Collaboration: The REU program joined another REU program site to build unity, professional skills, and share research. The REUs were then exposed to different types of research as well as receive feedback from a different perspective.
- Electronic Portfolios (e-portfolios): Students used e-portfolios to document their deliverables, experiences, and research throughout the ten weeks. The REU Program selected the Portfolium platform due to its similarity to other social media sites. Students created ten posts that focused on reflection. Posts included descriptions, teammate tagging, and the skills learned. The intention was for students to develop stronger transferable skills [3].
- Deliverables: Students developed a literature review, perfect pitch, and a research poster during the process. One community college participant shared that they were helpful tools during the learning process.

During the ten-week program, students were immersed in various professional development and deliverables that allowed participants to be successful.

CUREs and UCORE

Other than a lack of research opportunities at community colleges, students also face additional barriers like the lack of awareness of existing opportunities, unclear of the possible benefits of research experiences, the unknown of cultural norms associated with research as well as their own financial and personal reasons. To increase more participation from community college students for research programs, institutions have begun offering an introduction to research course called course-based undergraduate research experiences (CUREs) in community colleges. They have found it can address and reduce the barriers to be able to expand more opportunities for students [4].

Another approach that has provided an opportunity for two-year institution undergraduates in research is at the University of Oregon. By addressing one of the "critical leaks" of education (transition between a two-year institution and four-year institution), they started an undergraduate research program called Undergraduate Catalytic Outreach and Research Experiences (UCORE). It is funded through the Science, Technology, Engineering, and Mathematics Talent Expansion Program (STEP). The purpose of the program is to recruit students who do not see their full potential as a researcher, particularly in engineering and science. The program includes 20 to 30 community college students broken into small groups to participate in the areas of research in physics, chemistry, and geosciences each summer. The program has shown to have a significant impact as most have transferred to a four-year institution as well as providing a sense of community and empowerment to the students. The participants then return to their home institution as an ambassador to lead at their school as well as encourage their peers to pursue research [5].

These are examples of purposefully exposing and recruiting from community colleges for research programs and the impact of inclusivity. As it is not necessary to have exclusively all community college participants, the approach for CUREs and the UCORE program provide an ideal framework to embrace two-year institution students in REU Programs.

Data Collection

The data was collected based on pre- and post-surveys. Of the 12 REU participants, four were from community colleges. All attended the same community college in the county in which the university of the REU Program is located.

All the community college participants were male, 75% were under the age of 25 and 25% of the participants were in the 30-34 age range. Half the community college participants were Hispanic students. One community college participant was a disabled military veteran. All were transitioning to a four-year institution from a two-year institution. Three were transitioning to the university in which the REU program was held with another transitioning to a different university. Two participants were sophomores, and two were juniors. The community college

participants fields of study were; Civil Engineering, Computer Engineering, Mechanical Engineering, and Aerospace Engineering.

The pre- and post-surveys focused on topics such as engineering self-efficacy, feelings of inclusion, career success, engineering creativity, and global kinship based on Assessing Women and Men in Engineering (AWE)'s Longitudinal Assessment of Engineering Self-Efficacy (LAESE) assessment design [6] as well as Ragusa [7] literature. The data interpreted for this paper was based on a Likert-scale.

Culture of Diversity

To create a diverse environment, recruitment was purposeful. The Education and Workforce team developed a partnership with a local community college. The Education Director visited the local community college to present to students and faculty. The intention was to encourage community college students to apply to the program. Program participation required Calculus I, Calculus II, and Physics to ensure student success. As part of the culture of the REU program, regardless of background and experience, all were equally important and significant to the group.

In the 2018 REU Program, 33.3% of the participants were from community college with 50% being from underrepresented populations. Community colleges can play a pivotal role for preparing underrepresented populations for STEM careers as 55% of Hispanics and 45% of African Americans who possess a bachelor's or master's degrees in science and engineering began at a community college [8]. In addition, students from community colleges bring different and unique experiences as some have previously been in the workforce or served in the armed forces.

Research is a significant component of using the content learned in the classroom and applying it in a real-world context. As important as it is for REU Programs to recruit from community colleges, it is just as significant for the students to engage in a research program. When community college students participate in REU Programs, they build relationships and gain opportunities.

Impact

All the community college REU participants reported that they would recommend our REU program. Students shared that they felt welcomed, and the program engaged and helped to encourage them through the process of their research. They shared that 100% of their goals were met from participating in the program. They felt that the deliverables were helpful, and it forced them out of their comfort zones. The greatest impact was the advice received about pursuing graduate school. Also, students reported that their interest in STEM careers increased since participating in the REU Program. According to the survey, students also increased their confidence, skills, interest in graduate school, and found the program helpful in transitioning from a two-year program to a four-year institution.

Self-Efficacy

Self-efficacy is significant for achievement and persistence in engineering majors. To develop their self-efficacy, students need to develop technical and professional skills [8]. With the compared theories, self-efficacy is one of the greatest predictors of a career choice [9]. As seen in Tables 1 and 2 in the student-reported post-assessment survey, community college REU students shared that their research abilities improved along with confidence in their abilities as researchers and remaining in the engineering field in accordance with the REU program's stated goals.

Table 1. Self-Reported Research Skills Abilities

Statements	Average (5-point Likert-Scale)
The research skills I gained will help me in terms of future work or research experiences.	4.5
I gained experience in research practice.	4.5
I gained self-confidence as a researcher.	4.5

Table 2. Self-Reported Engineering Abilities and Success

Statements	Average (7-point Likert-Scale)
I can succeed in an engineering curriculum.	6.0
Someone like me can succeed in an engineering career.	6.5
I believed that I will do well.	6.5

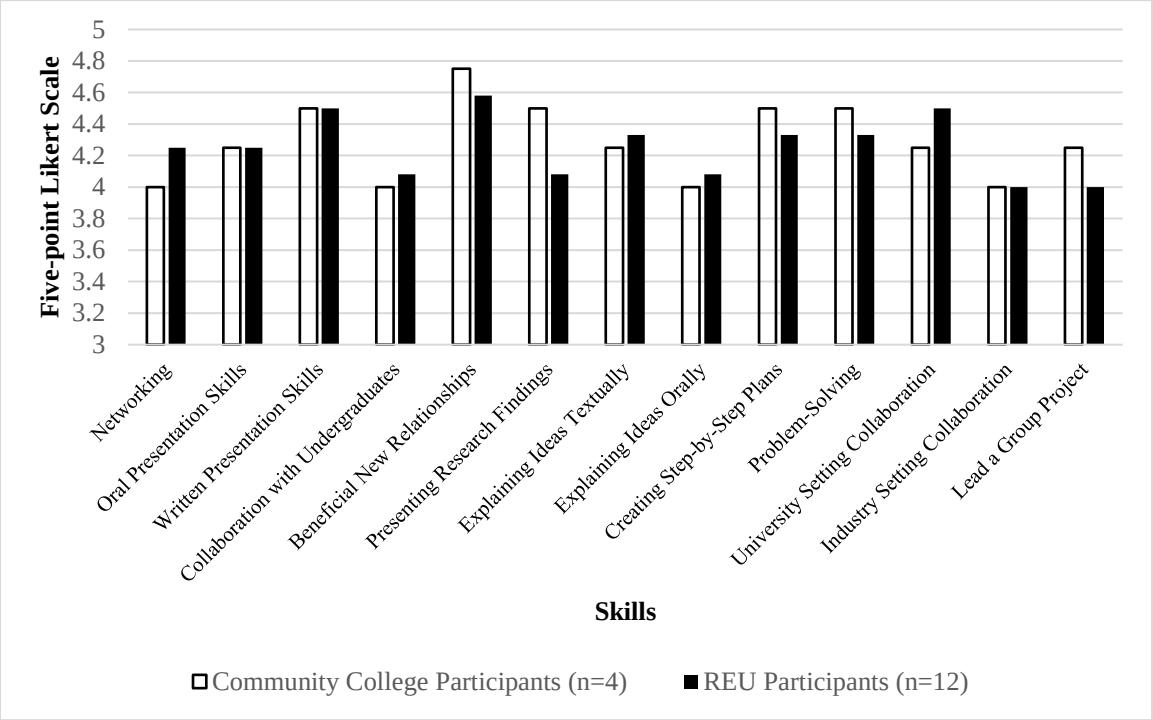
Mentoring

During the program, students are partnered with a PI and a Graduate Mentor based on their project interest and mentor compatibility. Mentorship is significant to the process, especially for the community college participants. The Graduate Mentors are the primary go-to person for the REUs. Mentorship was critical for the learning process, time management, providing resources and guidance, and building interpersonal relationships [10, 11]. For community college participants, this is crucial in developing confidence as well as the skills from the classroom during the research process. The community college students reported that their mentors provided research experience, scientific knowledge, career or promotional guidance, personal advice, and advanced material that pushed them beyond previous knowledge. As the four students shared different experiences, all could state that they gained a great deal of experience from their mentor.

Professional & Technical Skills

As students completed 40 hours of research per week and participated in technical and professional sessions, they learned vital skills to be an engineer. For community college participants, this opportunity is unique. As seen in Figure 1, all participants in the program

Figure 1. The comparison of the community college participants and the REU Program.



gained professional skills throughout the process as they self-reported a four and above on a five-point Likert-scale. The average reported by community college participants was higher than the REU average for gaining new relationships, presenting research findings, creating step-by-step plans, problem-solving, and leading a group project. Based on these findings, community college students gained research-oriented experience through the program.

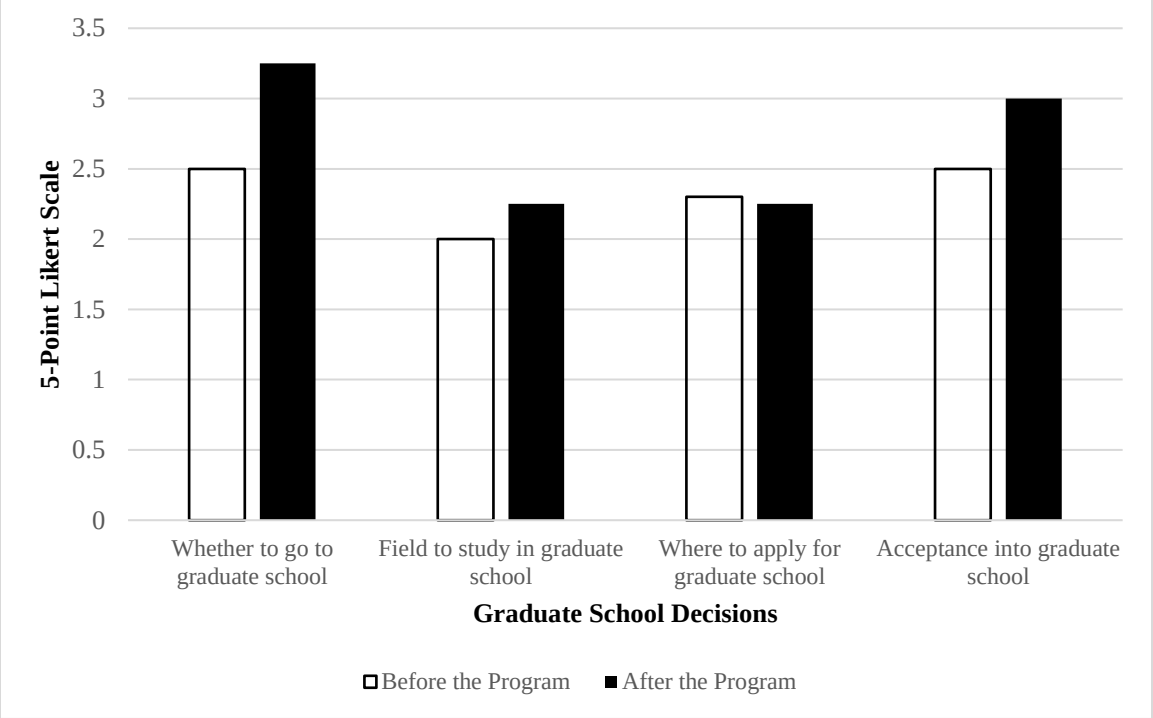
Graduate School

One of the purposes for any REU Program is to be a recruitment tool for graduate school. Community college students in the program showed an increase of 25% in interest for pursuing a master's degree and Ph.D. degree. Before the program, three participants were planning to pursue their master's degree, and two participants were planning to pursue their Ph.D. Following, all four participants were planning to pursue a master's degree, and three participants were planning to pursue a Ph.D. In Figure 2, students' graduate school choice, the field, and acceptance rate were most influenced by the REU Program. All community college participants were looking to complete STEM-related majors such as: Astrophysics, Structural Engineering, Computer Engineering, and Biomedical Engineering.

Transitioning

All four students planned to transition to a four-year institution. The program did not influence the students' decision to go to a four-year institution nor were they selected due to their decision.

Figure 2. Students comparison of their initial decisions in the pre-survey to their decisions at the end of the REU Program.



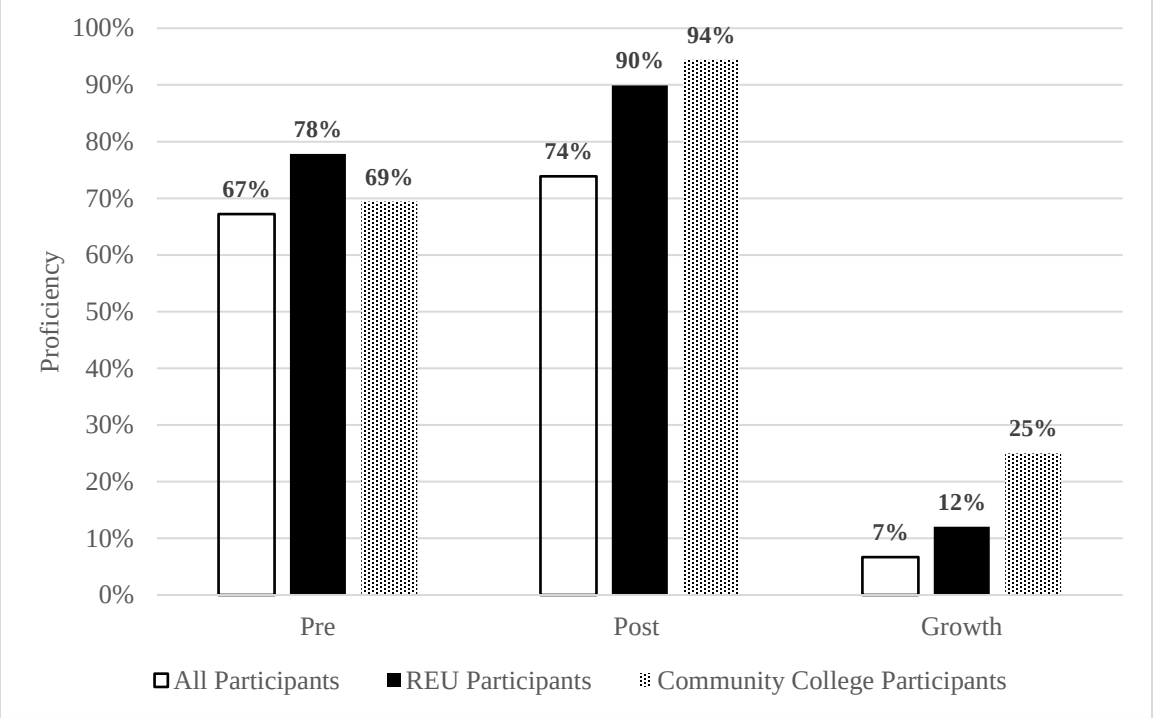
On a seven-point Likert-scale, students felt that they could approach a staff member or faculty (6.5) and adjust to a new campus environment (6.25). Students were able to become familiar with the transportation, food hall, culture, and environment of the campus as well.

Exposure to Emerging Technologies

The REU program immersed students in emerging technologies like renewable energy, power electronics, and WBG semiconductors. The one-day workshop was a significant technical session for our students. They were provided onsite and hands-on training in a technology that is highly marketable. The training began with an overview of basic electrical engineering concepts with a focus on power electronics. The emphasis was then put on semiconductor devices before introducing WBG devices and describing their future impact. The REUs not only learned the technical skills required for implementation of WBG devices but had an opportunity to apply the content that they learned during the course. It provided clarity and understanding of their current research.

The WBG Lab participants included students from the REU (n=12) and Pre-College Programs, including the Young Scholars (n=6) consisting of high school students, and the Research Experience for Teachers (n=2) from middle and high school technology and engineering programs. All participants were given a pre-assessment with nine questions related to the WBG course. In the post-assessment, participants were given the same questions, but in a different order through Qualtrics. The assessment was designed by the Ph.D. student who taught the workshop.

Figure 3. Comparison of the average WBG assessment of all participants, REU participants, and community college REU participants.



The growth in Figure 3 represents the change in proficiency from the pre-assessment to the post-assessment. Additionally, Figure 3 shows that the community college participants scored 9% less than the combined REU participant average before taking the course. However, community college REU participants had the highest average proficiency and growth from the WBG course.

This course demonstrated the utility of technical workshops focused on emerging technologies for community college participants. Even though they may never have been exposed to the material, community college students had higher improvement and scores than the REU average. We are recruiting for emerging technologies which is a high-demand field. Community college participants shared their interest in the field of power electronics after the workshop:

> *"I would definitely consider it. I am currently unsure of what field specific[ally] I am planning to go into."*

> *"I would consider a career in power electronics because power electronics is still in its youth..."*

The one-day WBG course provided unique technical training and exposure to WBG technologies which is a field critical to domestic manufacturing and national security.

Potential Improvements for the Program

There are two main improvements for community college participation of the REU Program. First is to prioritize mentor training and graduate mentor selection by selecting graduate students who have experience with supporting community college students. Additionally, we hope to improve the diversity of the community college participants by recruiting more women and other underrepresented populations. Despite having notable community college participation, we aim to diversify the representation further. Moving forward, we are partnering with an additional local community college to increase our recruitment from these institutions.

Conclusion

An REU Program can provide an opportunity to develop self-efficacy, obtain mentorship, improve professional and technical skills, prepare for graduate school, and be an instrument for the transition. By providing community college research experiences, a larger and more diverse applicant pool may become a major asset to domestic STEM workforce recruitment. According to a National Academy of Engineering report, "the success of engineering is based on a deep reservoir of talented people" and "we aspired to an engineering profession that will effectively recruit, nurture, and welcome underrepresented groups to its ranks [12]." Through research experiences, community college students can be engaged to diversify the workforce in the area of emerging technologies. These students need to be recruited, nurtured, and welcomed into the engineering field.

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