Board 421: Using Interdisciplinary Engineering Design Challenges Coupled with Career Exploration to Develop an Engineering Identity in Low-Income Students

Dr. Ricky T Castles, East Carolina University

Dr. Ricky Castles is an associate professor in the Department of Engineering at East Carolina University. He primarily teaches courses in the area of electrical and computer engineering with an emphasis on digital electronics and microprocessor-based courses. His research focuses on broadening access to engineering for low-income students and transfer student success.

Dr. Chris Venters, East Carolina University

Chris Venters is an Associate Professor in the Department of Engineering at East Carolina University in Greenville, North Carolina, USA. He teaches introductory courses in engineering design and mechanics and upper-level courses in fluid mechanics. He earned his Ph.D. in Engineering Education from Virginia Tech in 2014, and his research primarily focuses on conceptual understanding in engineering mechanics courses. He received his M.S. in Aerospace Engineering from Virginia Tech and his B.S. in Aerospace Engineering from North Carolina State University.

Using Interdisciplinary Engineering Design Challenges Coupled with Career Exploration to Develop an Engineering Identity in Low-Income Students

Abstract

East Carolina University (ECU) was funded by a multi-institutional Track 3 S-STEM Grant #1930497 in January 2020. The funds from this grant have been used to recruit and support three cohorts of students at ECU and three partnering community colleges. The project is referred to internally as the PIRATES project for Providing Inclusive Residential and Transfer Engineering Support. In addition to funding scholarships, the research aim of this project uses Lee and Matusovich's Model of Co-Curricular Support for Undergraduate Engineering Students [1] to study best practices in co-curricular support for both students who start their pathway towards an engineering degree at a university and students whose higher education academic pathway began at a community college. Major goals of the project include building a sense of belonging and an engineering identity among students both within and across cohorts and institutions.

One of the ways that this project has worked to encourage student retention and persistence in engineering is through engineering design challenges coupled with related presentations from speakers working in a variety of engineering careers. The goals of these events are to showcase the many opportunities engineering students have and the many ways that engineers work to solve local and global issues by having students engage in small engineering projects that can be completed in one day and showcasing how those projects relate to a broader field of engineering. The projects extend the experiences students have in various engineering courses and labs and introduce some technical skills that students may not develop in traditional classrooms and lab courses.

This paper will highlight the design problems posed to students during single-day design activities in which students from all cohorts and participating institutions were invited to work in teams to tackle design challenges. Student teams were purposefully assigned to get students working together who attend different institutions and are in different graduating classes to create mentoring opportunities for less experienced students to learn from more experienced students. Emphasis is also placed on how students were introduced to career opportunities related to the design challenges by recruiting alumni from the partnering institutions to speak on the work they do and how their educational pathways prepared them for diverse careers. This paper will also discuss survey and focus group interview data from students participating in these activities to showcase how the activities may have helped to expand their knowledge of opportunities available to engineers in a variety of fields.

Rockets and Advanced Manufacturing, Fall 2021

The first collaborative design challenge involved students working in teams to develop a custom nose cone for a model rocket. Students were given the dimensions of the fuselage tube and were asked to use SolidWorks to design a custom nose cone that could be 3D printed to replace the nose cone that came in the rocket kit. When students signed up for the event they were asked if they had already taken a drafting/CAD course and were asked what their experience level was

with using SolidWorks. Using this information along with information about which campus the students were from and their expected graduation date, students were then assigned to a design team. Each design team was added to a Microsoft Team and given instructions to schedule a meeting of their team so they could collaboratively develop their custom nose cone. The PI took special care to ensure that Teams were balanced with students who felt they had strong SolidWorks skills and those who did not feel as confident. The teams were also intentionally created to incorporate students from both ECU and community colleges. The students were given deadlines for when the SolidWorks models of their cones must have been submitted prior to the event so the parts could be 3D printed before the event. The cones were then printed and brought to the event.

On the day of the event, students gathered at Lenoir Community College. The day began with students eating breakfast together. The student teams then began assembling their rocket kits in teams. Over lunch, a guest speaker shared with the team how they use 3D printing to develop prosthetics for people who have lost limbs. The career speaker showcased how the artificial limbs are manufactured and showed various products to the students. Upon completion of the speaker's presentation, they picked the winner of the 3D printing design contest by choosing the team with the best nose cone from the cones that were 3D printed. The students then completed building their rockets and the day culminated with students launching the rockets with both the standard nose cone installed and the custom nose cones. Small accelerometer modules were installed in the rocket payloads to collect data about altitude and acceleration. A total of 24 scholars signed up to attend this event including students representing each of the 4 partnering institutions.

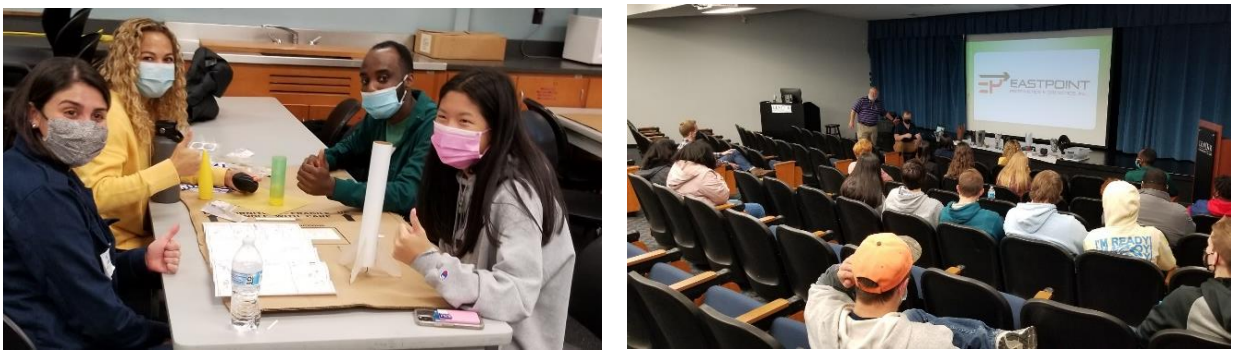

Figure 1 Left) Students work on a design challenge building a model rocket and integrating a custom, 3D printed nose cone. Right) Students attend a career presentation about 3D printed prosthetics and orthotics.

Sumo Robots, Professional Engineering Licenses, and the BioPharma Industry Spring 2022

The second all-day design challenge and career day including having students build sumo robots to compete against other teams in a tournament. Robots had to be built, wired, and programmed. The students who signed up to attend were once again placed into groups based upon their self-reported background knowledge in programming and circuit design. Groups were intentionally mixed to allow students to get to know students from other campuses. Four design teams competed in a double-elimination sumo robot tournament.

In the middle of the day, two speakers shared about career opportunities. One speaker was an alumna of the ECU engineering program and had just completed the process recently to become a licensed professional engineer. She shared about her experience working for a small local engineering design firm and getting to work on projects throughout the entire project life cycle from initial client meeting to product delivery. Another career speaker talked about engineering opportunities at a multi-national biopharma manufacturing company. Professionals from each of the companies represented engaged in mock interviews throughout the day critiquing student resumes and giving students practice interviewing for internships and full-time technical positions. A total of 20 students across all 4 participating campuses signed up to attend the event.

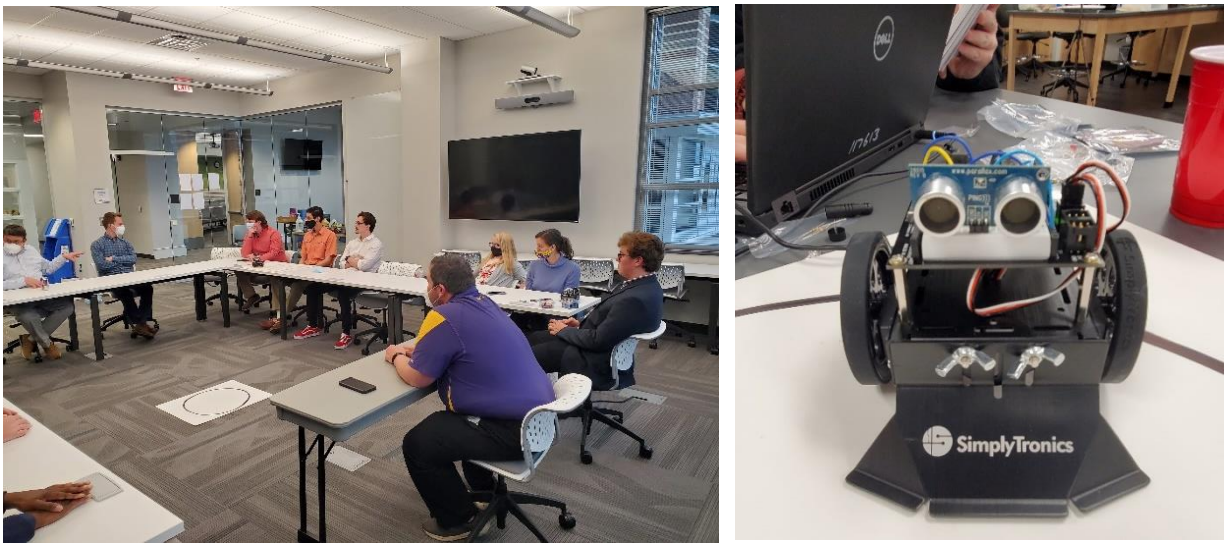

Figure 2 Left) Students and Faculty prepare for the Sumo Robot Competition, Right) One of the sumo robots with an ultrasonic sensor mounted on top to find an opponent and a bumper to push the opponent out of the ring.

Special Event at a Planetarium and Observatory, Fall 2022

In the Fall 2022 semester, the all-scholars event did not involve a design challenge, but instead included a special event at a planetarium and observatory. Scholars were invited to gather at twilight and enjoyed a picnic dinner. As the sun was setting, students were invited inside to a presentation in the planetarium. Once the sun set, students were able to observe the stars in an area with limited light pollution and were able to observe Saturn with a large telescope in an observatory. A total of 21 students signed up to participate in this event, with participation including students from 3 partnering institutions.

Creating an Incubator, Spring 2023

In the Spring 2023 semester, the focus of the design-challenge was bioprocess engineering. The design challenge required teams of students to develop an incubator that could be used to create yogurt. Students were given foam board insulation and had to create an enclosure for the incubator. They were also given an Arduino Uno board and some electronic and mechanical parts that could be used in the incubator design including fans, a relay and light socket, a thermistor and assorted wire. The students used the thermistor to measure the temperature inside the incubator via analog input into the Arduino. If the temperature was too high, the fans could

be turned on to blow hot air out of the enclosure and if the temperature was too low, the relay was used to turn on an incandescent bug light that could add heat to the enclosure.

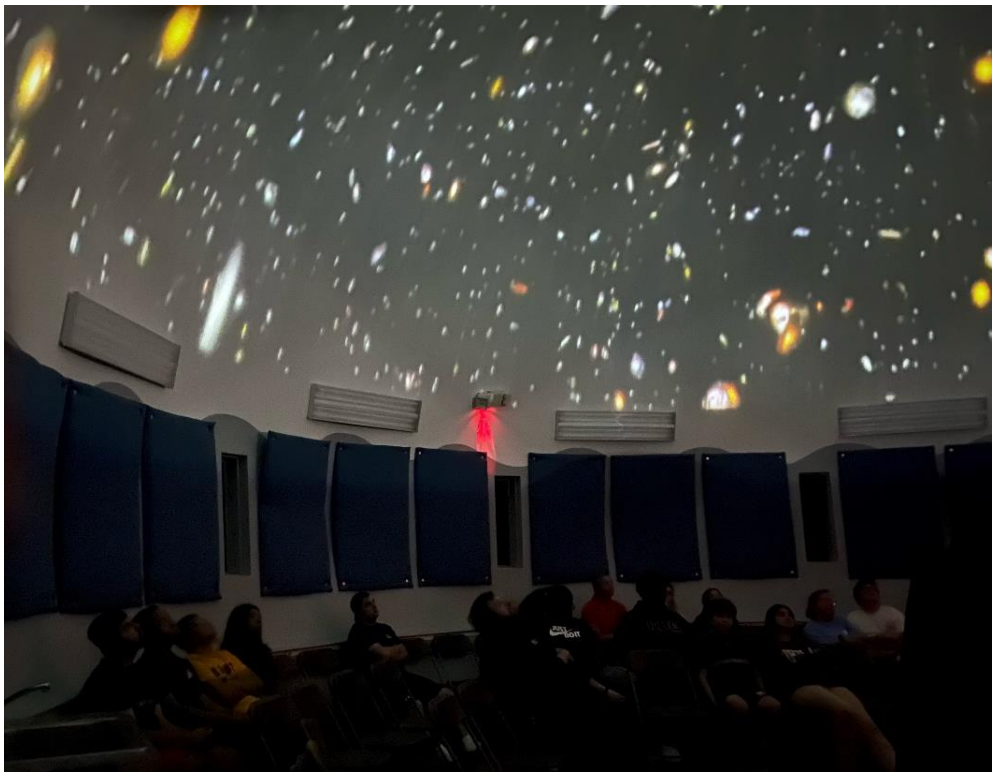

Figure 3 Scholars group in planetarium.

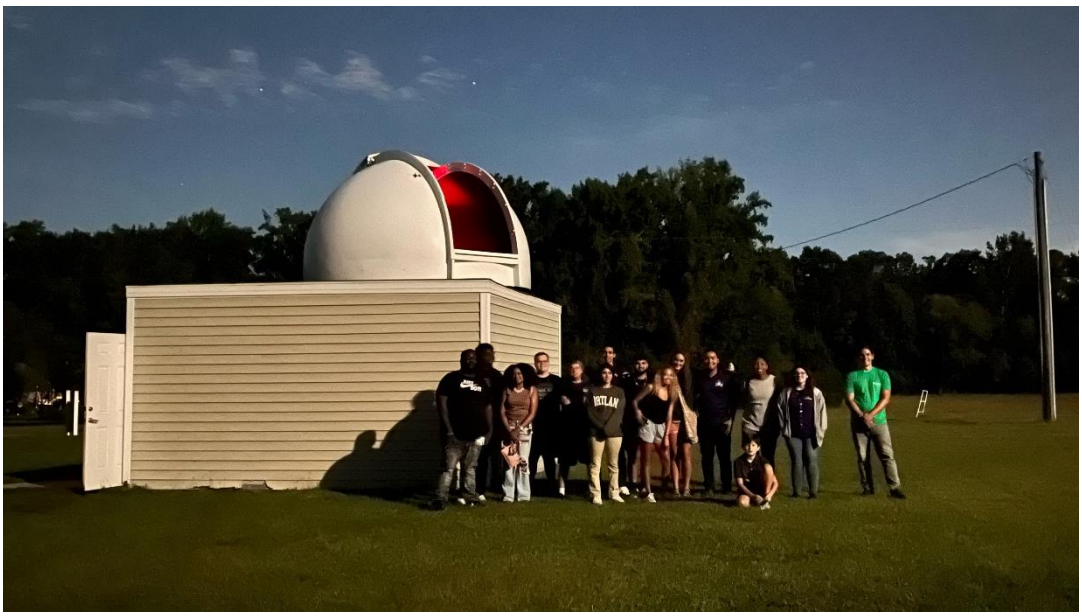

Figure 4 Scholars group in front of observatory.

In addition to the design challenge, students saw presentations from 2 alumni representing different biopharma companies. One of these companies is involved in the manufacture of various pharmaceuticals and biologics. The other is a validation specialist who is contracted by various biopharma companies to ensure their facilities are reliably producing product within governmental regulations. This event was hosted in the newest building on campus and the day's events also included lab tours of some of the new bioprocess engineering facilities courtesy of the director of the Eastern Region Pharma Center.

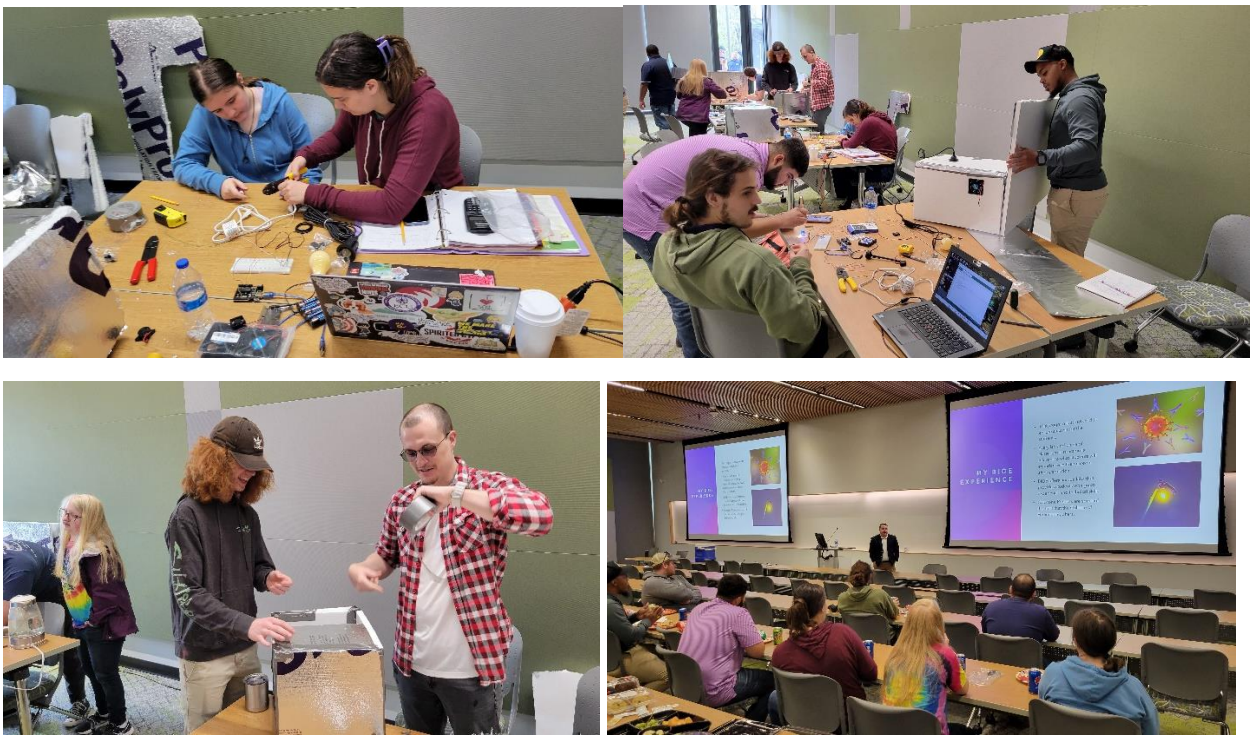

Figure 5 Top row and bottom left) Students work on building their incubator. Bottom right) Students listen to career presentation from alumnus.

Developing Circuits Resilient to Flooding, Fall 2023

In Fall 2023, the emphasis of the design challenge activity was developing circuits that could withstand the elements outdoors in all seasons. Students built a city simulation on a poster board that included a simulation of traffic lights at a 4-way intersection and streetlights that responded to a light sensor to turn on or off as needed. Students were instructed that they not only needed to develop a working circuit, but the circuit must also be able to withstand spraying with water and even being dunked in water. Students were given project enclosure boxes, shrink tube, silicone sealer, and other supplies that could be used to prevent water ingress into their circuit. The career speakers included two alumni who work as electrical engineers in the electric utilities industry. One engineer spoke about his work in redesigning parts of the local electric grid to raise power wires so they would be less prone to being impacted by flooding in the event of a hurricane or major storm. The other spoke about his path to an engineering career starting as an electric

lineman and working his way up to being VP of engineering for a local electric cooperative. At the end of the day, students demonstrated their circuit's capabilities by turning off the lights, using a spray bottle to spray the circuit, and dipping the project enclosure in a bucket of water to see if it still functioned properly.

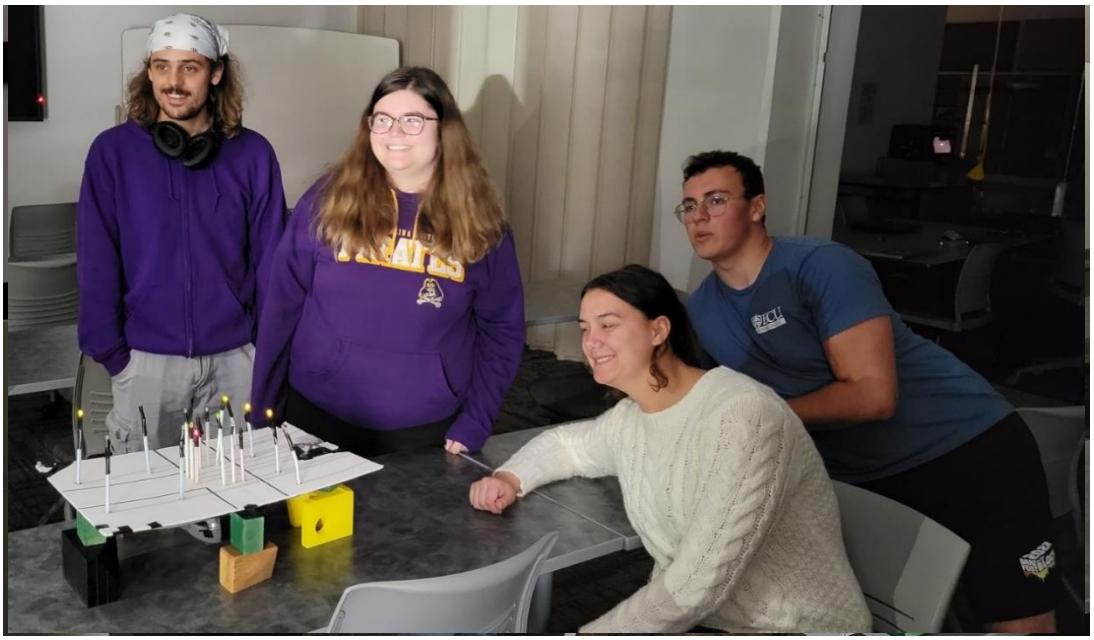

Figure 6 Scholars demonstrate their working city simulations by showing the lights turning on in the dark.

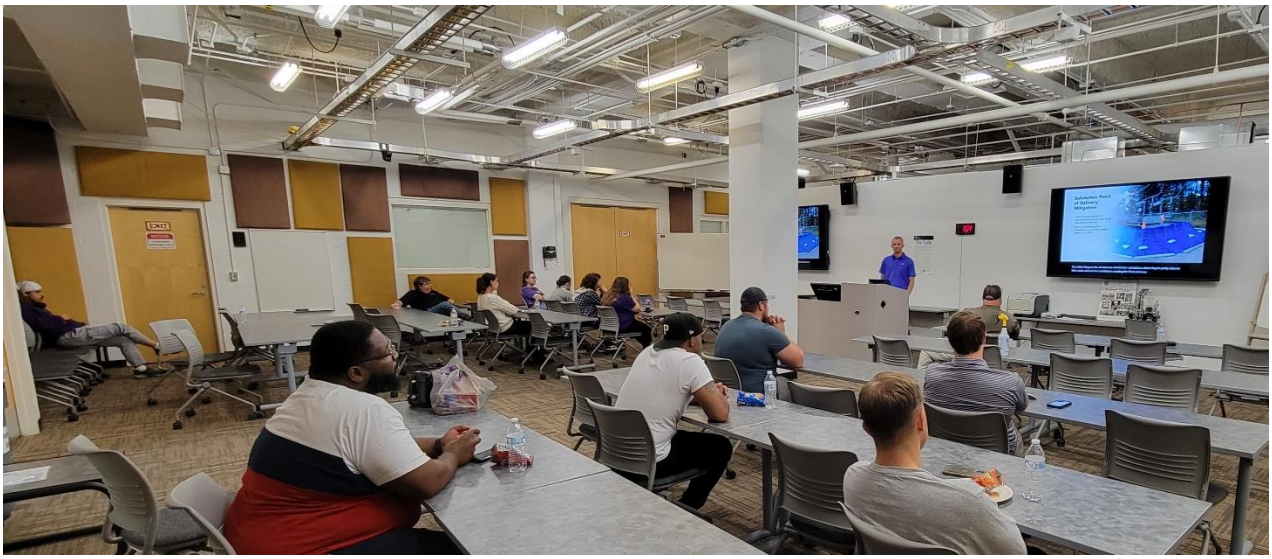

Figure 7 Students listen to a presentation about developing a flood resilient electric grid from an electrical engineering alumnus.

Student Survey and Focus Group Data

Each semester, the PI team has collected data using the Engineering Student Integration Instrument [2]. This instrument was developed by Dr. Walt Lee at Virginia Tech. Questions in this instrument ask students about their experiences as engineering students including their academic and social experience, their professional development, and their feelings of belonging at the university. This instrument was deployed at the end of semester for several semesters and was given to all scholarship supported students and to other students in the same academic cohort as a control group. While it is impossible to determine if these scholar events are the sole reason that students feel they have certain overall sense of belonging or integration in the engineering profession and at the university, the goal of these activities among several other high impact practices is to foster a sense of engineering identity and integration. Based upon the survey data presented below, the PI team believes students are developing a strong sense of integration into engineering and the university.

Baseline Data from Scholars, End of Fall 2020 semester

The Fall 2020 semester still had in place many Covid-19 related protocols. Many of the students in the first cohort of scholars had started at ECU and then moved back home. We were unable to host any in-person, hands-on design activities due to the pandemic. We did, however, have many online meetings with scholars that semester in order to maintain engagement and to work with students so their needs were understood while they were studying at a distance. The following questions and their responses were gathered after the first semester scholars were enrolled in the program and includes responses from 10 scholars.

Table 1 Baseline Survey Data from First Cohort of Scholars after 1 semester of engineering student. This table includes responses from scholarship recipients only. Data Collected January 2021.

	Strongly Disagree	Disagree	Somewhat Disagree	Neither Agree nor Disagree	Somewhat Agree	Agree	Strongly Agree
I can positively interact with other engineering students.	0	0	0	2	1	4	1
I can effectively work on teams with other engineering students.	0	0	0	1	2	5	2
I can effectively communicate in a professional manner.	0	0	0	0	2	4	4
I can effectively perform as an engineer in a professional environment.	0	0	0	2	2	3	3
I have leadership skills that will be useful as an engineer.	0	0	0	1	3	3	3
I have technical skills that will be useful as an engineer.	0	0	0	3	0	3	4

I have traits that are attractive to companies that hire engineers.	0	0	0	2	1	3	4
I am comfortable in professional settings around other engineers.	0	0	1	1	1	5	2
I can interact with practicing engineers in a professional manner.	0	0	0	1	3	2	4

Table 2 Baseline Survey Data from Engineering Students at ECU after 1 semester of engineering study. This table includes responses from students in the Fall 2020 entering cohort of engineering at ECU, but NOT scholarship recipients. Data Collected January 2021.

	Strongly Disagree	Disagree	Somewhat Disagree	Neither Agree nor Disagree	Somewhat Agree	Agree	Strongly Agree
I can positively interact with other engineering students.	1	0	0	6	5	5	1
I can effectively work on teams with other engineering students.	1	0	2	3	5	5	2
I can effectively communicate in a professional manner.	0	1	0	0	4	9	3
I can effectively perform as an engineer in a professional environment.	1	1	0	7	4	4	1
I have leadership skills that will be useful as an engineer.	1	1	0	1	1	12	2
I have technical skills that will be useful as an engineer.	1	0	0	2	5	8	1
I have traits that are attractive to companies that hire engineers.	1	1	0	2	7	7	0
I am comfortable in professional settings around other engineers.	1	0	1	5	5	5	0
I can interact with practicing engineers in a professional manner.	1	0	1	6	0	4	5

In April 2024, the external evaluator on the S-STEM project from NC State University's Industry Expansion Solutions conducted focus group interviews about the impact of the various supports in place for students and followed up with a written survey for students unable to attend the focus group interviews. The evaluator reported from the focus group interviews that:

> "Respondents appreciated that industry representatives were invited to talk about the career landscape in their respective fields (and that there was always an emphasis on local companies)" ~S-STEM Project External Evaluator

When asked about the activities, student comments included:

> "*The PIRATES program has allowed me to meet people working in the biomedical field in Greenville. I have also gotten to know people outside of ECU through the events and competitions that are hosted."~S-STEM Scholar 1*
>
> *"[PIRATES] Has given the understanding of teamwork and community in the work place. It's really nice being in a program where others have the same motivations and drive as me" ~S-STEM Scholar 2*
>
> *"The community building is good. The events I have gone to are always insightful and interesting to hear about what my fellow pirates scholars are up to." ~S-STEM Scholar 3*
>
> *""I think this is one of the best opportunities I have gotten to be a part of. I've gotten to know my fellow students, professors, and the Greenville community in a way I wouldn't have thought to."~S-STEM Scholar 4*
>
> *"I have made friends in the program as well as networking with peers and professors."~S-STEM Scholar 5*

Conclusions

While it is difficult to isolate the impact of a few all-day design challenges on the development of technical skills and competencies and overall professional development, students have learned quite a lot during these design challenges and keep interacting with these programs to learn more about their profession and to hone their skills. Students overall have confidence in their skills and their ability to engage in the engineering profession. The comments from students in response to focus group questions and the survey provided by the external evaluator indicate that the various activities of this S-STEM project, including design challenges and networking activities have allowed them to develop a professional identity, to learn about career opportunities, and to have a sense of belonging at the institution and in the engineering profession.

References

[1] Lee, W. C., & Matusovich, H. M. (2016). A model of co-curricular support for undergraduate engineering students. Journal of Engineering Education,105(3), 406–430. https://doi.org/10.1002/jee.20123

[2] Lee, W.C., Godwin, A. and Nave, A.L.H. (2018), Development of the Engineering Student Integration Instrument: Rethinking Measures of Integration. J. Eng. Educ., 107: 30-55. https://doi.org/10.1002/jee.20184