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Robotic Opportunities for Rural Communities: Building a STEM Pipeline for K-12 Students

Fiona Litiku, New Mexico Institute of Mining and Technology

Fiona has helped with the New Mexico Tech outreach for a year now, and with the Robotics competition that is a result of the outreach program. She is a teaching assistant for college freshman in the NMT Mechanical Engineering department, allowing her to see first-hand the general scope of knowledge gained from K-12 education in New Mexico. Continued work with the outreach program has allowed Fiona and her co-authors Thomas Pierson, Matthew Tyrrell, and Dr. Curtis O'Malley to see how the outreach program is affecting local students. Fiona's work towards the outreach program has increased research and data collection for STEM education dissemination.

Dr. Curtis John O'Malley, New Mexico Institute of Mining and Technology

Assistant Prof at NM Tech since 2016. Teach junior/senior design clinic as well as 1st semester introduction to mechanical engineering design. As part of these courses I work closely with national labs and industry to maintain course projects with real

Matthew Luis Tyrrell, New Mexico Institute of Mining and Technology

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Fiona Litiku, Thomas Pierson, Matthew Tyrrell, Dr. Curtis O'Malley
Mechanical Engineering Department
New Mexico Institute of Mining and Technology

Abstract

The Mechanical Engineering Department at New Mexico Tech hosts a robot combat competition annually, with attendance from K-12 schools across the state. The goal of the competition, as part of the mechanical engineering outreach program, is to build students' interest in engineering and robotics while developing a pathway to a career in STEM. As attendance for the competition increases each year, students and teachers get more involved with robotics while learning about engineering education and careers.

Advanced engineering topics can be taught to all students of various backgrounds through the implementation of accessible and interactive teaching programs. This method of teaching ensures that students develop self-efficacy that provides them with the confidence to pursue a STEM career. At NMT, one of the main objectives is to provide experience with robotics in ways that interest students and foster a continued space to explore different STEM career pathways. Every year, students around New Mexico work with teachers to build combat robots for competitions hosted by NMT. Through the creation of specialized robot programs to construct, test, and compete with battle robots, engineering education becomes more interactive and fun, rather than daunting and out of reach. The more interactive our programs are, the greater they serve as opportunities for students deciding to pursue STEM, all while learning the necessary skills to do so. The skills learned in the program will be useful for students as they move to college and into the workforce.

New Mexico has a challenge when dealing with STEM education and outreach because it is a largely rural state with many communities that are far from urban centers (that have more opportunities for those interested in engineering than their rural counterparts). Thus, education efforts must be designed in a way that is accessible in more isolated, rural communities, while also being affordable, thereby creating STEM opportunities for these communities. New Mexico Tech has created a curriculum for designing combat robots where students and teachers are given materials for learning robotics with the assistance of online guides and long-distance mentors who call and assist in robotics education. By creating a network of education resources, New Mexico Tech runs a program that involves and engages students from across the state at an advanced level.

Programs like the one here at NMT can be made even more accessible by incorporating community into engineering education. NMT and other organizations around the state host and

participate in community events, which expand the reach of the program. These events also function as a means to connect STEM teachers and students around the communities of New Mexico, building support for teachers and the outreach program. This gives K-12 students as well as their teachers and parents yet another opportunity to learn about STEM careers and education near them. Community involvement allows engineering education to be integrated successfully into schools across the state and generate excitement among students and teachers alike for participation in engineering programs.

Introduction

The goal of Mechanical Engineering Outreach at New Mexico Tech is to increase interest in engineering across the state, encouraging students to consider pursuing higher education and careers in STEM fields. This is accomplished through remote education and hosting outreach events. The outreach program compiles and distributes resources for teaching students in K-12 to create robots, sensor systems, and automated devices via collaboration with college engineering students. These high quality educational resources are designed to be low-cost and accessible to learners from both rural and urban backgrounds while increasing diversity amongst participants. These resources teach students how to build robots for a competition, bringing together kindergarten to college students, teachers, and industry professionals.

Outreach Efforts

MechE Mayhem

Since 2020, NMT has hosted an annual robotics tournament for K-12 and college students from across the state and beyond. Anyone can sign up for the tournament, including alumni, faculty, staff, and the general public. Each year, participation has increased significantly, going from 12 competitors in 2020 to 350 competitors in 2024, with the majority coming from 40 schools in New Mexico (*Miner Mayhem 2024 Robotics Tourney Exceeds All Expectations, 2024)*. MechE Mayhem consists of five different arenas for robot combat that run matches simultaneously, with space for judges and audiences. Teams compete in an elimination bracket with different competitions for each robot classification. The tournament is made up of six competition categories: foam MESA bots, 3D-printed MESA bots, 150 gram bots, 3 pound bots, 30 pound bots, and 60 pound bots. The outreach education team at NMT offers materials and support for teachers and students looking to build 150 gram robots and MESA bots. MechE Mayhem also acts as a large social and networking event for teachers, engineers, professors, and even state representatives. The tournament provides a space for student teams to compete in the outreach supported categories, but also allows the students to interact with college-level robotics. In this way, MechE Mayhem helps to bring together the robotics and engineering community around the state.

Preparation for MechE Mayhem begins the semester before the competition with interested schools and teams deciding on which of the events they would like to compete in. Teams can order a kit from the NMT outreach program containing all necessary parts and a variety of instructional materials to build their robot. Teams can also meet online with students from NMT to help build and design their robot throughout the semester.

Robotics Lessons Offered

Arduino Basics

Arduino basics lessons are created by the NMT Mechanical Engineering outreach team to give students an introduction to Arduino. A team of students can order an Arduino basics kit, which contains an Arduino as well as many different sensors and devices. There are six cumulative lesson plans: *Basic Concepts of Electronics and Electrical Circuits, Arduino* B*asic Concepts Applied to LED Circuits, Reading Data From an Arduino Sensor, Coding an Ultrasonic Sensor, Servo Control*, and *Completing a Sound Meter*. These lessons are designed to teach all of the basic capabilities of Arduino microcontrollers, regardless of prior coding knowledge. Each lesson consists of a background information document for students to read through, as well as separate worksheets for teachers and students. This can give students a fundamental knowledge of the coding and wiring necessary for robotics through a self-paced course. Students anywhere can develop coding skills with just the Arduino kit and the worksheets.

MESA Combat Bots

Kits for the MESA combat bots are sent out upon request which include an Arduino, motors, and all the other components necessary to build a simple robot. NM-MESA is an organization devoted to supporting K-12 students in gaining college readiness in math and science that works with NMT to promote robotics. There are eight lessons for the MESA bots: *Electronic basics, Introduction to Arduino Programming, Wiring your MESA bot, Reading Values From Your Controller, Controlling Your Motors' Speed, Controlling Your Motors' Direction, Sending Outputs To Your Motors*, and *Building Your Robot Chassis*. These MESA bot lessons include documents, worksheets, and video lessons that a team can complete at their own pace. All online instructional modes allow any student with access to a computer to build a MESA bot, regardless of location.

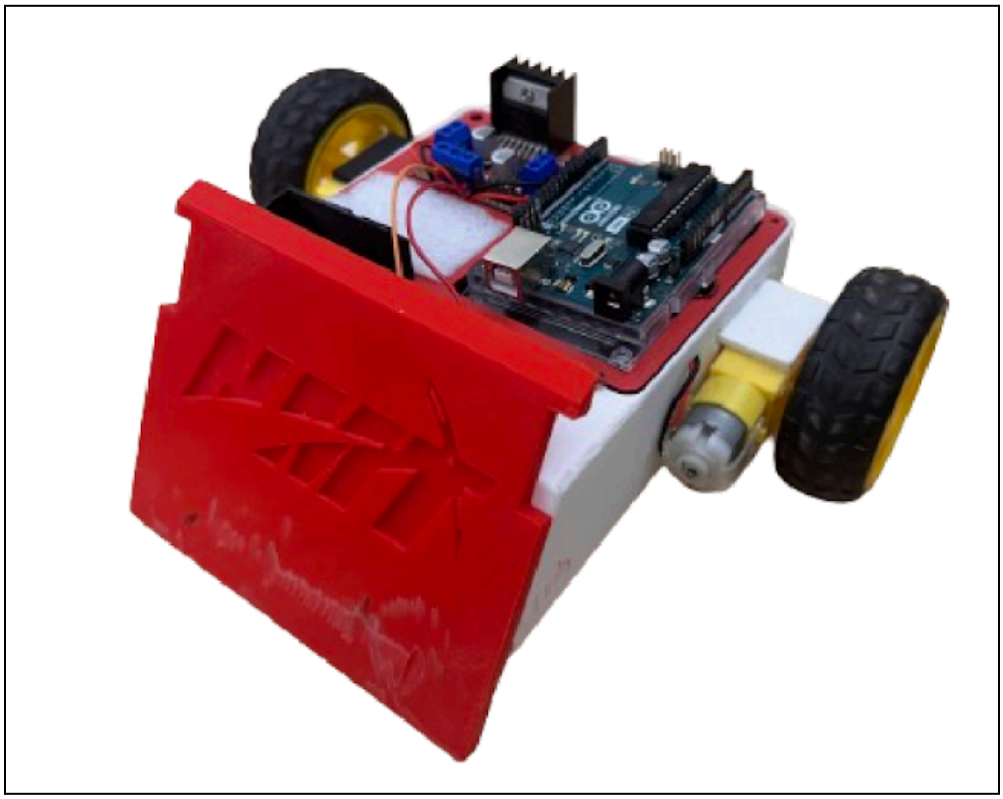


Figure 1: Completed Example MESA Bot with Arduino Circuit

150 Gram Combat Bots

150g robot kits are sent out upon request which include electronic speed controls, a remote, motors, and all the components necessary to build a small scale combat bot. There are two lessons for the 150g combat bots: *Combat Robot Safety* and *Wiring Your 150g Bot*. These lessons are instruction manuals with pictures that a team can follow along with. Constructing a 150g robot requires the use of a soldering iron, so these robot lessons are geared toward high school and college teams. While more resources are necessary to build 150g robots, the kits and lessons provided make the 150g robots as accessible as possible.

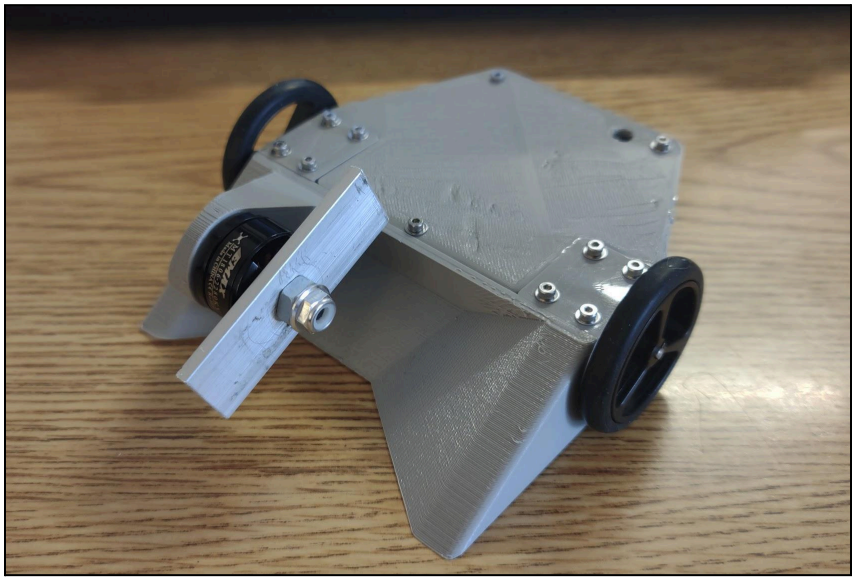
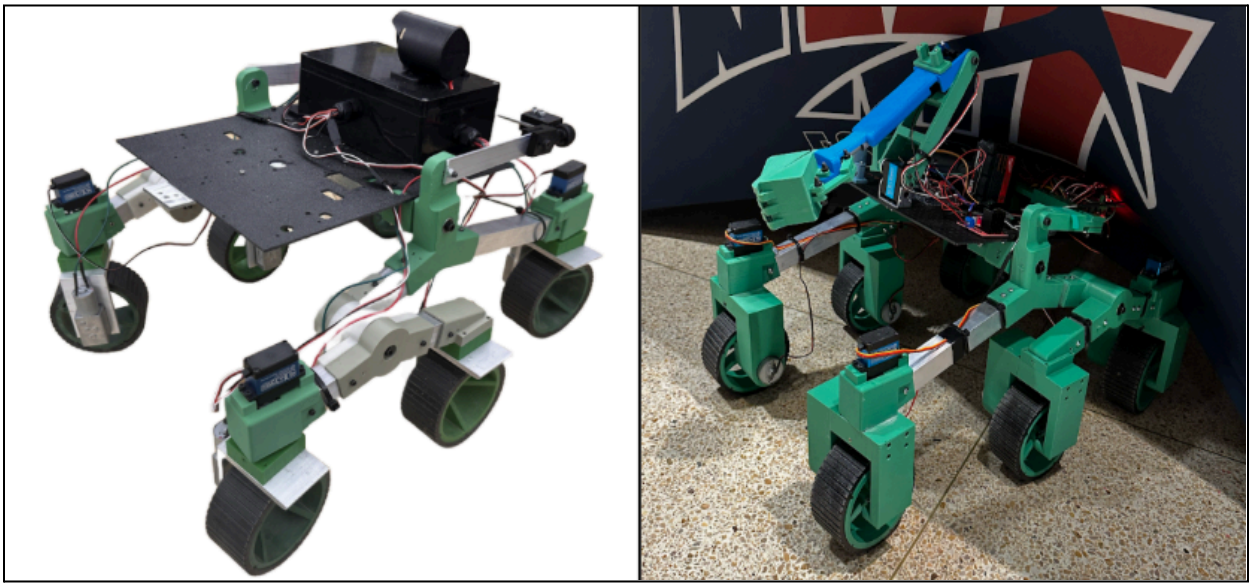


Figure 2: Completed 150 Gram Robot

Space Rover

Space Rover kits are for high school and college students as well, and include all of the electronics and motors necessary to run the bots. There are two lessons for the Space Rovers: *The Mars Rover Subsystems* and *Rover Assembly Instructions*. These lessons are instruction manuals with pictures that teams can follow to construct their own rover and rover subsystems. Unlike other robots that are supported by the outreach program, the rover is not a combat robot, and the purpose of the rover can be chosen by the team. Teams work to design subsystems that fulfill the chosen purpose using the materials they have available, which can range from cardboard to 3-D printed parts.



Figures 3 & 4: Space Rover Driving frame (left) and Rover with Arm Subsystem (right).

Demonstration

Building interest

It is widely recognized that the first step in creating a STEM pathway is sparking that initial fascination for STEM (*Exploring Stem Engagement in Girls in Rural Communities: Results from gems clubs, 2020).* Demonstrations showcase the work done in the New Mexico Tech Mechanical Engineering department, ensuring that students of all ages have hands-on experience with robotics. These robotics demonstrations encourage additional schools each year to participate in MechE Mayhem by generating excitement in combat robotics. At these demonstrations, students can drive each of the different robotics projects: MESA bots, 150g bots, and the rovers. Through rallies and other events, NMT recruits new teachers and school teams to participate in robotics programs throughout the state.

Outreach Events

Besides MechE Mayhem, New Mexico Tech is involved in a multitude of outreach programs and events throughout the year. NMT visits several schools and participates in science conventions that encourage a deeper understanding of the diverse pathways that encapsulate STEM careers. The first type of outreach event that New Mexico Tech hosts are rallies at schools around the state with NM-MESA. These rallies help build interest in both the NMT robotics programs and the MESA programs. At these rallies, NMT brings trailers and arenas for crowds of hundreds of teachers and students from the area to battle with pre-built robots so everyone can learn more about the program and join. Last year, NMT hosted four MESA rallies across the state in high schools in Chaparral, Gadsden, Las Vegas, and Albuquerque, each providing for a region of around 12 schools.

Virtual Learning

The driving factor in accessing rural communities throughout the state is the ability to teach with virtual learning tools. Through virtual learning, students can access the materials that they need, and NMT representatives are available online to offer assistance. The online lessons are formatted such that they don't need to be taught in a face-to-face environment, facilitating self-paced education. By providing teachers with the resources necessary to be robotics educators, more students can be reached. This allows the lessons to be effectively passed off, making robotics knowledge more accessible to those communities that can't feasibly be reached in person regularly.

Due to the physical size of New Mexico, the virtual learning environment also offers options for connecting cities with the program, even if they are not rural communities. It is nearly a four hour drive from Albuquerque to Las Cruces, two urban centers of the state; therefore, virtual learning helps to make communication possible between cities without expending many resources. Virtual instruction allows for teachers and NMT representatives to find times that work for all parties involved, and usually yield more frequent meetings than that of in person instruction.

Impact On the Students Involved

Outreach Research

One of the main reasons for the success and increased engagement within the outreach program stems from constant data collection. Using feedback from the program, lesson plans are made more user friendly and understandable for students who may not have any robotics experience. A future goal of the outreach research is to translate the online lessons to Spanish and Navajo, which are the two most spoken languages in New Mexico besides English (*US Census Bureau*). Translating and eventually creating videos for the lessons in all three of the most common languages will break down another barrier for STEM education, increasing accessibility for students and teachers whose first languages are not English.

Participants in MechE Mayhem are surveyed to obtain data on the effect of the program. The outreach research attempts to assess any shift in self-efficacy and sense of belonging in STEM communities. This will allow the program to be tailored so that engagement numbers continue to increase yearly.

At the 2024 MechE Mayhem tournament, 86% of the participating teams were a part of NM-MESA. According to statistics published by MESA on the students in the program, 89% of MESA students are minorities, 72% of the students' parents have never attended college, and 58% of the students live in a rural area, as defined by the USDA Research Services. Additionally, 51% of the students were female, 44% were male, and 5% were another gender (*Mesa Schools / Facts & Figures,* 2024).

In a survey conducted after the 2024 MechE Mayhem tournament, a statistically significant number of K-12 participants were asked about whether they were planning to attend college, and whether they intended to pursue a STEM-related degree or occupation. 88% of the respondents said they were planning to attend college, and over half the students were considering a STEM degree or career.

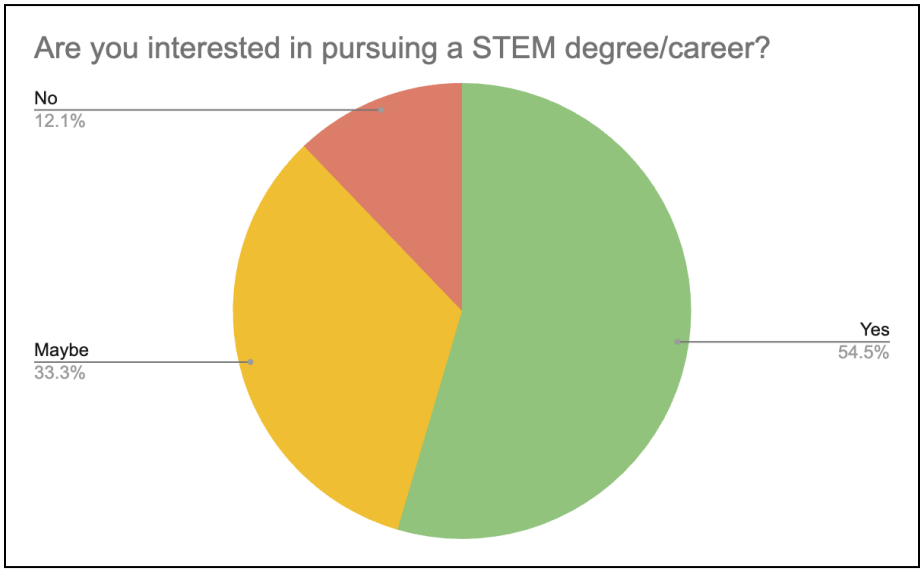


Figure 5 : A pie chart showing K-12 MechE Mayhem participant's interest in pursuing STEM careers/degrees.

STEM Pipeline

A STEM Pipeline refers to the creation of an environment that encourages students to pursue an education, then ultimately a career, in a STEM field. This is done by giving students access to STEM activities and education as early as possible, which acts as a way to build interest and excitement regarding STEM while removing some of the anxiety that can come with engaging in STEM communities. The outreach program intends to help students become more familiar with

science and math topics from a younger age, so that by the time they are applying to college and entering the workforce, they are more likely to pursue the field.

An aspect of the outreach efforts is to encourage students to see that STEM is applicable to any desired career. The outreach program serves the rural communities of New Mexico, where many students pursue careers such as agriculture, but aren't always aware that STEM topics are relevant to these careers as well. A way to help students recognize different pathways is to leverage students' local rural knowledge and experiences, which are important components of effective K-12 STEM education in rural settings, creating place-based learning experiences through local partnerships and the adaptation of instructional materials for local relevance (*Rural Areas Offer Unique Opportunities for STEM Education, But Targeted Resources, Connectivity, and Training Needed*, 2024). Focusing on teaching in these historically underserved communities, and promoting all the options available for these communities and individuals reinforces the STEM pipeline.

A further obstacle to the inclusivity and diversity of STEM communities is stigma against certain people's abilities, which oftentimes leads to the dismissal of ideas. This dismissal, especially at a young age, can cause students to feel like they don't belong in STEM. The NMT Mechanical Engineering Outreach Department strives to foster environments where every student is heard. Students that participate in the outreach program are incentivized to consider engineering and apply to NMT if they want to pursue robotics, which can further solidify their path into a STEM career. The STEM pipeline continues during the intro to mechanical engineering course offered at New Mexico Tech. Students are encouraged to get hands-on experience with robotics, completing their own projects that allow them to get a head start on all of the exciting aspects of Mechanical Engineering. NMT creates an engaging curriculum and an environment where students feel comfortable asking for help, fostering a culture of retention in the mechanical engineering department.

Areas of New Mexico Reached

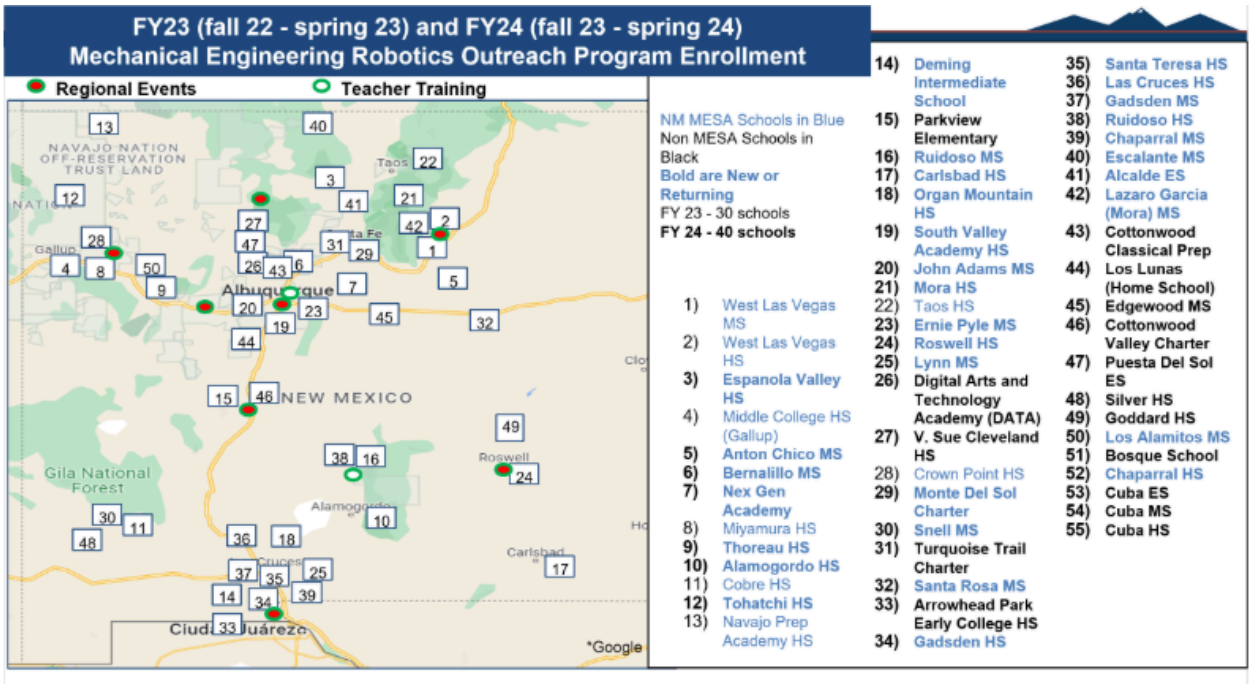


Figure 6: Map of New Mexico schools that participated in robotic outreach in 2023

The outreach program has been able to support robotics education across the state. The program operates in the ten largest cities of the state (US Census), as well as other smaller towns and rural areas of New Mexico.

Conclusion

When building a STEM pipeline for rural and underrepresented students from K-12, it is important to consider all the nuances that come with it. The main problem faced, especially when considering rural communities, is making STEM education accessible. This is done in many ways, such as making online lessons and resources available for students regardless of proximity to New Mexico Tech. An important part of promoting education in STEM is by showing students how STEM can be used in many different careers. There can be a false impression that valuable contributions to STEM only arise outside of rural communities, but rural areas often have a plethora of local opportunities to pursue STEM education. The goal of the outreach program at NMT is to build interest in STEM overall so that teachers and students both have the initiative to explore robotics and other topics. With the increased engagement in the outreach program each year, NMT can continue to accommodate these rural communities across the state through creation of captivating, accessible STEM education that is available regardless of location.

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FIONA LITIKU
Fiona Litiku is currently a junior Mechanical Engineering student at New Mexico Tech who has participated in the robotics outreach program for one year.

THOMAS PIERSON
Thomas Pierson is currently a junior Mechanical Engineering student at New Mexico Tech, who has assisted in the robotics outreach program for two years.

MATTHEW TYRRELL
Matthew Tyrrell is currently a Master's Mechanical Engineering student at New Mexico Tech who has assisted in the robotics outreach program for two years.

DR. CURTIS JOHN O'MALLEY
Assistant Prof at NM Tech since 2016. Teach junior/senior design clinic as well as 1st semester introduction to mechanical engineering design. As part of these courses I work closely with national labs and industry to maintain course projects with real world application. The products of the class and research projects are then tailored to hands-on activities for K-12 STEM education outreach.