

A University–Community Partnership Model to Support Rural STEM Teaching and Student Engagement

Kathleen Kavanagh, Jan DeWaters, Seema Rivera, Melissa Carole Richards, Michael Ramsdell, and Ben Galluzzo, *Clarkson University*

Rural economically disadvantaged communities face unique challenges in engaging students in science, technology, engineering, and mathematics (STEM). School district administrators, teachers, and students do not have access to high-quality STEM opportunities compared to urban schools. This article describes a partnership between a small, private STEM university and a network of school districts scattered across the geographically isolated region of upstate New York. The partnership's primary goal is to support the teaching and learning of STEM. This is achieved through actively engaging a range of university and community stakeholders in STEM enrichment and professional development. Programming includes summer camps and after-school activities, challenges and competitions that focus on inspiring students to pursue STEM careers, undergraduate and graduate student mentors, and a university curriculum designed to prepare teachers to work in high-need school districts. Activities are supported by the university's Institute for STEM Education, which fosters collaborations for like-minded faculty and campus members to pursue grant opportunities and connect with community members. The paper describes various program components and how they work to support each other, discusses impacts of the program, and describes ways in which elements can be implemented elsewhere.

Keywords: Rural STEM education, outreach, partnerships, competitions, K-12 outreach

University and K-12 school partnerships create Science, Technology, Engineering, and Math (STEM) educational opportunities for K-12 students, university students, and both teachers and faculty. These collaborations have a combined purpose: to improve student outcomes and experiences. According to Robinson et al. (2017), shared attributes of quality partnerships between schools and universities include a shared vision, institutional leadership, communication and collaboration, shared ownership and accountability, alignment and sustainability, and responsiveness to the local context. This paper describes successful professional and collaborative practices between rural K-12 schools and a STEM-focused university located in the same rural region.

Rural America affords individuals the outdoor recreation spaces they seek to boat, fish, ski, hike, and more. Others may seek rural areas to be near family or friends. However, rurality has challenges in terms of educational opportunities. STEM teacher shortages that exist in most K-12 schools across the country are even more prevalent in rural areas. Recruiting and retaining teachers in rural areas is difficult; smaller communities are tied to less funding, which means lower

teaching salaries, higher poverty rates, geographic isolation, and a limited pool of potential faculty applicants. For a combination of these reasons, rural areas are often seen in an unfavorable light (Aragon, 2016). Rural students tend to have fewer opportunities for engaging in STEM learning opportunities (Boettcher et al., 2022). In addition to limited resources because of limited funding, the challenges are often exacerbated by the fact that many rural areas lack access to broadband connectivity (Croft & Moore, 2019; Saw & Agger, 2021). Issues of access are worsened for students of color in rural areas (Horrigan & Duggan, 2015).

Teachers in rural schools face unique challenges. In addition to a general lack of access to materials and programming, teachers may often teach multiple subjects because there are fewer faculty and staff. At the same time, rural teachers tend to know students and their families well because they may have taught a sibling or parent of their student; many times, the school district is one of the larger employers in the area, so teachers may even know parents who work in the school. Preparing preservice teachers to overcome unique barriers in rural schools can increase equitable access to effective STEM education for rural students (Azano et al., 2019).

The community–university partnership described in this work is located in St. Lawrence County (SLC), situated in rural Northern New York State (NYS). SLC has the second highest poverty rate in NYS, at 18.9%, and nearly 27% of the county’s children live in poverty (Lawton, 2021). Approximately 15,000 students in grades PK-12 are educated in 18 rural SLC school districts, including nine very small districts of only 600 students or fewer. All districts share the same problems of limited resources and significant poverty rates, with more than 50% of the students eligible for free or reduced lunch. Along with poverty, students are at risk of not completing high school or functioning below academic standards. In 2021, 13% of the population over the age of 25 had no high school diploma, and another 35% only had a high school diploma. Only 33% of the population had a bachelor’s degree compared to 38% for NYS. Student achievement is impacted by regional poverty. The NYS 2018 math test data indicate that 16 SLC school districts had less than 50% of their students achieving proficiency. One school had zero students score proficiency in grade eight.

Student enrollment in upper-level math and science courses is comparatively low. The 2018–2019 NYS Education School Report Card data (NYS School Report Card) indicate that only 14.7% of SLC students were enrolled in physics, and 44.7% were enrolled in Algebra 2. The small number of students who successfully complete upper-level science and math courses translates to only a few students who are adequately prepared to enter STEM majors in college.

Clarkson University (CU), located in the heart of geographically isolated SLC, is a small, private STEM university with a long history of community outreach. CU has strengths in training STEM leaders and STEM teacher leaders with a successful Masters of Arts in Teaching (MAT) program, STEM departments, and an Institute for STEM Education. Administrative leaders committed to cultural change and a growing number of teachers with a history of engaging in STEM initiatives have paved the path for continued success. In this region where popular and traditional STEM venues such as science centers and high-tech industry are limited or non-existent, CU is a regional magnet of science and engineering excellence, partnering with local businesses, community-based organizations, and licensed professionals to offer students and teachers alternative and effective STEM content.

One of CU's early initiatives was the Project-Based Learning Partnership program funded by the National Science Foundation (NSF), which engaged over 90 partner teachers, 3100 students, and 70 SLC students, and focused on project-based modules in the classroom (Powers & De Waters, 2004). The program received national recognition for the middle school "Energy Systems and Solutions" curriculum, which won the 2009 Premier TEACH Engineering Curriculum Development Award for K-12. The program inspired the growth of outreach activity and, in 2004, created the Office of Educational Partnerships (OEP) to solidify the institutionalization of outreach at CU (Powers et al., 2008).

For several years, educational outreach activities at CU were coordinated through the OEP. The Institute for STEM Education was established in 2016, subsuming the roles of the OEP and providing the university with a larger hub for K-12 Outreach and STEM teaching support. Professors participate as affiliates or are appointed as faculty in the Institute. Two graduate student fellows support the Institute's outreach initiatives as well. Undergraduate students are recruited and trained to assist with programming, volunteer at events, and mentor high school students. The Institute also advises students in CU's pre-teaching minor, which facilitates transitioning into CU's MAT program. The MAT program is further supported by an NSF Noyce grant, which provides scholarships and training to develop high-achieving STEM college students, into STEM Teachers, preparing them specifically to work in high-need school districts. In 2021, CU partnered with 14 universities to research rurality and STEM teacher preparation, seeking to answer questions related to how teacher preparation programs prepare students to work in rural areas and what factors effectively retain STEM teachers in rural school districts.

This article demonstrates a variety of opportunities created through university-K-12 partnerships in a rural area (Figure 1). The paper describes how one university works with multiple rural school districts, sharing how the work is implemented, and the challenges, and finally providing recommendations for practice – particularly for other STEM-focused universities in rural areas. All educational programming and opportunities have certain complexities and regular practices; the intent here is to focus on specific challenges and opportunities of implementing STEM teaching and learning partnerships in rural areas, providing details for a few of CU's most noteworthy programs.

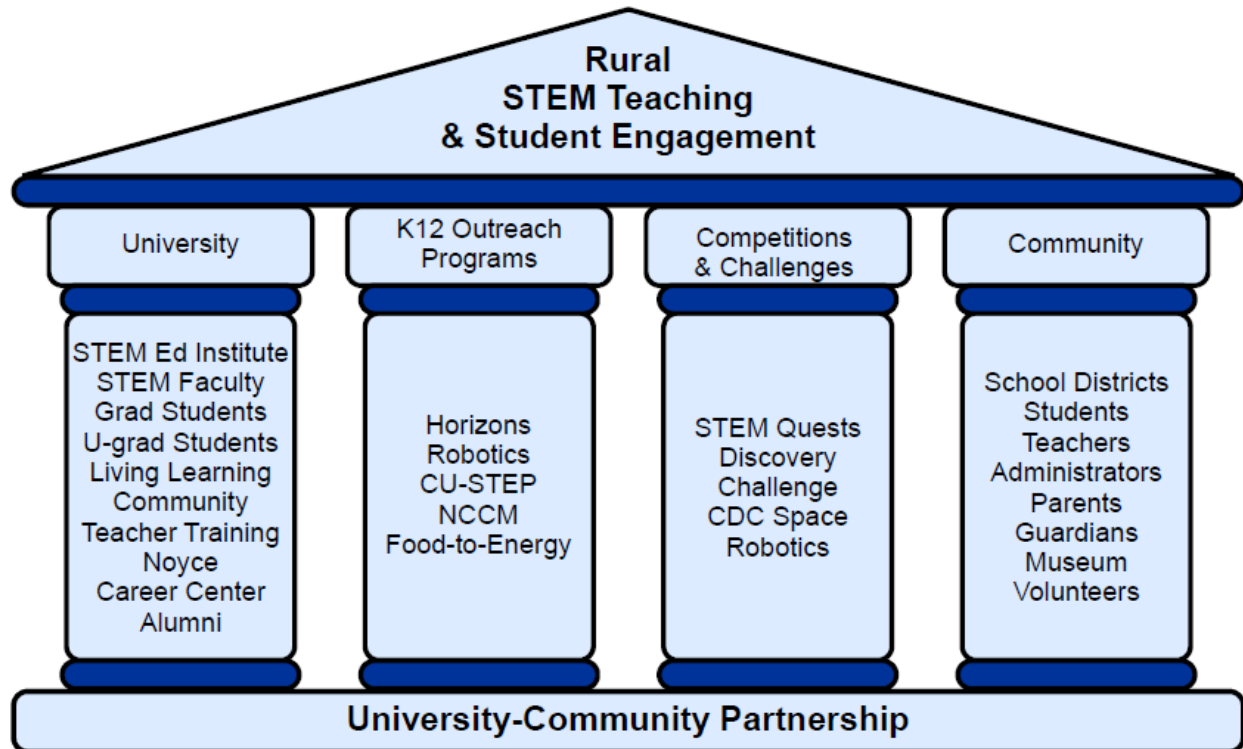
K-12 Outreach

This section highlights two prominent outreach programs, describing how they leverage partnerships to support teachers and inspire both pre-college and college-aged students. One is a grant-funded program and the other requires tuition fees, with needs-based scholarships widely available through the local Board of Cooperative Educational Services (BOCES) district.

CU's Science and Technology Entry Program (CU-STEP) has been in existence at CU since 2006 and is jointly funded by the NYS Education Department (NYSED) and the University to support approximately 200 students annually in grades 7 through 12, from 12 different school districts spread out across northern NYS. The target audience is students who are underrepresented minorities or economically marginalized students; however, the majority of students are eligible based on free or reduced lunch.

Figure 1

University community partnerships and several examples of programming that support rural STEM teaching and student engagement

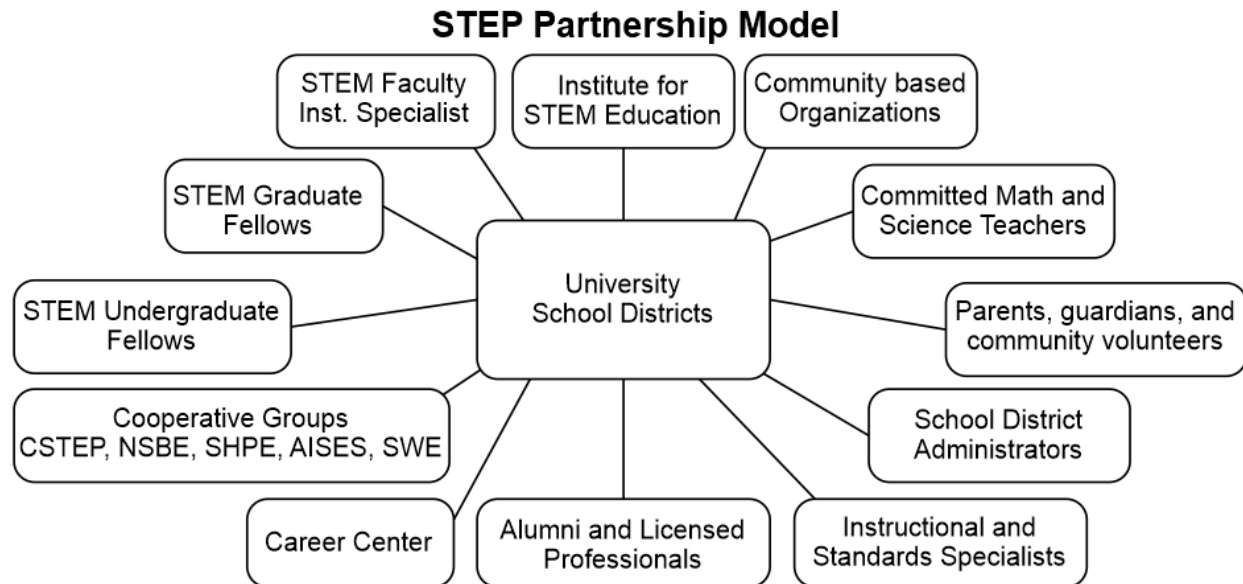


CU-STEP provides students with academic enrichment and research experience in science, mathematics, and technology content areas and consists of summer and academic year components. The program's success relies on a teacher coach in each school district who recruits eligible students and meets with them on a weekly basis. They are supported by two graduate student fellows who visit the schools once per month and assist with activities. A wide range of campus resources supports this program and strong relationships with school districts are essential in recruiting and retaining students, as seen in Figure 2.

Central to the curriculum are project- and problem-based learning principles, focusing on students being actively involved in learning through collaborations to solve a real-world problem (e.g., Kokotsaki et al., 2016). CU-STEP activities range from computer programming game challenges, conducting original research projects for a statewide competition, and interacting with college mentors and licensed STEM professionals to designing and analyzing a model roller coaster. The program's mentoring component pairs college students with participants so that they can discuss choices being made at critical times that pave their way toward college and careers (Rivera et al., 2019).

Figure 2

Partnerships in CU-STEP Model, including many campus societies: College-Science Technology Entry Program (CSTEP), National Society of Black Engineers (NSBE), Society of Hispanic Professional Engineers (SHPE), American Indian Science and Engineering Society (AISES), and Society of Women Engineers (SWE).



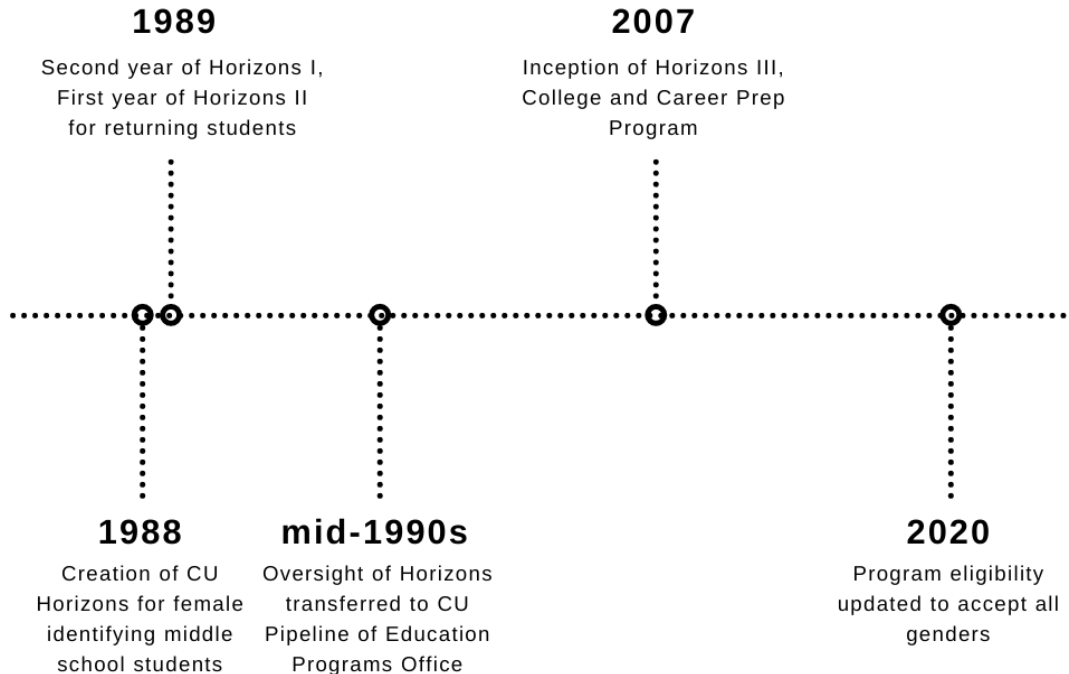
Once per month, the students across all school districts visit campus for a workshop that includes STEM enrichment activities, college and career readiness, or individualized research projects. These workshops are typically led by CU community members and supported by about a dozen undergraduate student volunteers. For example, the director of the Career Center created an immersive mock job fair experience where students role-play as job seekers equipped with resumes and others act as employers with the goal of finding a good fit. Similarly, staff from CU's Educational Resource Center has introduced the idea of mind-maps (Buzan 1995; Buzan & Buzan, 2006) as a tool for students to use for decision-making and research projects.

Campus visits are an integral part of overcoming the isolation of the region. In particular, there are few opportunities for teachers to spend valuable networking time with other educators in their disciplines, and campus visits facilitate those much needed interactions. Student participants have expressed that the campus visits are their favorite activity. Interaction with college students and exposure to the labs and facilities on campus sparks conversations about their future plans. Moreover, they meet students from across three counties, and with the program's strong retention rate, new friendships are formed. Students in this cohort often suffer hardships that lead to a range of emotional and mental health issues. These social gatherings can offer some relief, as food and prizes are provided at each event.

The program culminates with a week-long summer day camp focused on engineering and motivated by designing roller coasters (Wick, et al 2011, Fowler & Turner, 2010). Using a project-

based learning approach, students form “roller coaster design companies” with three divisions corresponding to the grade levels: “Concept Engineers” (grades 7-8); “Design Engineers” (grades 9 - 10); and “Safety Engineers” (grades 11 - 12). Teachers act as company CEOs. Students learn the underlying grade-specific STEM content to design a roller coaster. A roller coaster card deck was developed to assist student companies with the design process that incorporates a series of linkable track segments. Only certain card combinations result in a feasible roller coaster. Concept Engineers act as the initial roller coaster architects, developing the preliminary design, including a scaled blueprint and a wire model. Those plans are passed to the Design Engineers who alter the original segments to ensure the coaster has enough energy to complete the ride. Safety Engineers then check the g-forces exerted on riders as they enter and exit turns, loops, and inversions to ensure safety. The final design is programmed within a simulation software package, where it can be “ridden” from a first-person perspective so students get to virtually experience their coaster in CU’s Motion Simulator Laboratory. A trip to Six Flags® theme park allows students to collect sound-level, temperature, altimeter, accelerometer, and heart rate data on real roller coasters and other park rides for analysis. Parents and school building leaders are invited to a final showcase where students present posters about what they learned.

Horizons is a long-standing residential summer program that engages CU faculty and students to work with middle and high school students, the majority of whom are from underserved populations in STEM, in a tiered mentor system to (a) build self-esteem to perform and apply their skills so they can envision themselves in STEM-based field of study and careers; (b) build confidence through interactive, hands-on, cooperative learning experiences in which participants work together to solve problems; and (c) promote self-awareness, leadership, and team-building skills. The program was created in 1988 to provide outreach to female middle school students in the local region who had an aptitude and interest in math and science (Williams, 1990). Any young women who participated in the first year (Horizons I) were invited to attend the second year (Horizons II) of the program. In the mid-1990s, Horizons moved to the Pipeline of Education Programs Office (now the Diversity, Equity & Inclusion Office), in part because of similar youth programming efforts in that office, most notably a 10-week residential research experience that was supported by the National Institute of Health (NIH). Under new leadership Horizons quickly expanded its reach – eventually inviting participants from over 400 middle schools, many of whom returned for Horizons II. Due to the growth and positive impacts of Horizons I and II, Horizons III was implemented in 2007 to provide a third-year continuation opportunity. Originally created to serve young women, Horizons began accepting all genders in 2020 although it still primarily attracts female-identifying students. Horizons is currently operated by faculty in the Institute for STEM Education, with outreach to over 115 different school districts from 40 counties throughout NYS. Three programs run concurrently to serve over 250 participants per year. Horizons I is a mathematics- and science-based outreach program for students in grades 6 through 8. Horizons II, for students in grades 7 through 9, is based on mathematics and engineering. Horizons III is the third-year program for students in grades 9 through 11 and focuses on helping participants explore college and career preparation, with the aim of preparing them to enter programs well-equipped for success. As a further incentive, CU provides annual scholarships to CU undergraduate students for every year they attend Horizons. Figure 3 illustrates the timeline of the evolution of CU’s Horizons Program.

Figure 3*Clarkson University Horizons Program Timeline*

Over the years, school districts and the university have demonstrated value and commitment to ensuring Horizon's success. School administrators, counselors, and teachers are primarily responsible for program recruitment. Throughout CU, multiple departments and offices are vital to this effort, including the Diversity, Equity & Inclusion Office, Student Success, Marketing, Admissions, the School of Engineering, the School of Arts and Sciences, Office of Information Technology, and Campus Safety and Security. One faculty member's teaching load is assigned to administer the program within the Institute for STEM Education. These efforts have bolstered a widespread reputation for the Horizons program. They have leveraged lasting impacts through increased involvement of local teachers and student helpers and, more importantly, by preparing underrepresented students to enter STEM fields. A major outcome of the Horizon's program is that upon completion, participants will be able to make more informed choices when selecting high school courses and extracurricular activities that will lead to better preparation for college studies in these or similar fields. Since its inception, many of the participants in the series of Horizons programs have pursued undergraduate and graduate studies in STEM. Specifically, at CU, the Horizons program has been responsible for directing young women to attend CU in many STEM fields.

Engaging Undergraduate and Graduate Students as STEM Educators

The involvement of university students as educators and mentors is integral to most of CU's K-12 outreach programs. Knowing that students from high-need areas benefit most from mentoring (DuBois et al., 2002), ensuring that the rural K-12 students interact with college

students is essential for increasing the K-12 students' cultural capital, or the social knowledge and behaviors developed through mentoring relationships (Philip & Hendry, 2000). In addition, peer networks are beneficial in influencing rural students' interest in attending college (Chenoweth & Galliher, 2004). This section highlights some activities where college students play a significant role in achieving program outcomes.

CU's Food-to-Energy Project partners CU faculty and students with teachers and students at Canton Central School in a place-based learning experience focused on food waste issues and resource recovery (DeWaters & Grimberg 2021, 2022; Clarkson Food-to-Energy, 2022). The program integrates a school-wide food waste recovery system with curricular and extracurricular lessons in food systems, waste management, and resource recovery and incorporates mentoring to a great extent. Since 2018, CU has worked with teachers and students to organize and operate a food waste collection system in their school cafeteria, whereby students separate their food waste into collection bins at the cafeteria waste stations. A team of CU students advises and supports the middle school Green Team and high school Environmental Club to organize the cafeteria food waste collection system. CU students deliver the food waste to a nearby learning farm that is part of Cornell Cooperative Extension Service of St. Lawrence County (CCE), an educational outreach facility focused on food and agricultural systems. CU researchers have operated a demonstration-scale anaerobic digester at the CCE Farm since 2010; the school's food waste is added to the anaerobic digester feed, producing biogas to heat a greenhouse on the farm, animal bedding from the recovered solids, and fertilizer. Since the program started in 2018, approximately 16 metric tons of food waste has been diverted to the anaerobic digester, producing about 3,400 m³ of biogas and saving the school district approximately \$4000 in waste hauling fees.

The cafeteria food waste program offers an excellent opportunity for students to engage in place-based learning experiences that use the school as a living laboratory. CU students enroll in a credit-bearing project course. Mentored by CU faculty, students work in teams to develop and teach interactive, hands-on educational modules, so K-12 students learn the motivation for their cafeteria food waste program and the science behind anaerobic digestion. The CU students work alongside teachers in classrooms and after-school programs, serving the role of teacher/mentor. The project course consistently attracts a team of six to nine undergraduate STEM students, with several returning to the course a second or third time and many taking an interest in teaching. At least one student has been accepted to CU's MAT program because of the experience. The lessons they have developed cover a wide range of topics, from educational games about the food system to constructing mini compost cups and observing the biodegradation of food. Several are aligned with NYS Learning Standards. Each year CU students regularly work with the Canton middle school Green Team, an energetic group of about 15 fifth and sixth graders, and recently a second rural middle school has joined the partnership for an 8-week-long after school program that engages 10-12 youth of the same age. Two high school teachers have integrated a biogas experiment into their curriculum, which is tailored to specific course learning objectives (Burdick et al., 2021, 2022). For example, environmental science classes estimate the biogas produced from a typical dairy farm and the resulting impact on electricity-related CO₂ emissions, and chemistry classes learn stoichiometry and biogas potential for digesting various types of food waste. Field trips round out the experience. Students visit the CCE farm and come to CU's

campus to tour various sustainability initiatives, including the campus food digester, wind turbine, and LEED-certified buildings. In addition to the value of exposing students to the university, visiting with members of the CU food-to-energy team away from school provides another opportunity for mentoring on a different level. The Food-to-Energy project demonstrates how K-12 educational activities can be developed from university research projects, providing another avenue for university–community connections. The model can be applied to a range of research topics that are relevant to K-12 education. Curricular materials used in this program are available online (Clarkson University, 2022).

Informal education is another opportunity for college students to act as STEM Educators. In fall 2020, the Institute for STEM Education launched a new program with the local North Country Children’s Museum (NCCM). The curriculum fosters an engineering mindset by engaging participants in the design process (Cunningham, 2018). One 10-week class was offered to pre-K through third graders and another to fourth through seventh graders, both designed for the appropriate grade levels and meeting for about 45 minutes each week. The curriculum was entirely developed by two students (one undergraduate, one graduate) and was delivered by a team of undergraduate STEM students. Participants acted as toy engineers and were tasked to design and build interactive toys from cardboard (Adolph 2020; Heroman 2021). Activities included building a marble labyrinth, a marble wall-drop, moveable cardboard robot hands, stomp rockets, and using their imaginations to repurpose a large cardboard box. For each activity, students brainstormed, planned, drafted blueprints, and iterated through testing and improving their creations. Throughout, information about recycling was included and students were encouraged to reflect on their own household practices. Most important was that students at both levels were involved in engineering practices. Throughout the class, students considered constraints and trade-offs in their designs. They were naturally challenged to persist, problem solve, and consider multiple options for their creation to be effective. Students made authentic choices and communicated to the group about their final products.

This endeavor will become part of an undergraduate class on Community Engagement, which focuses on methodologies from multiple fields and from diverse perspectives to help students develop an understanding of the social impacts of engagement through community-based service partnerships. In fall 2022, about 65 students will take the course, supported by the CU Honors Program. After studying the historical and cultural contexts of engagement and service, students will explore a range of relevant issues, including university–community relationships, cross-cultural encounters, interpersonal conflict and consensus, power structures, the concept of privilege, and the meaning of equitable community partnerships and outreach. Students will read case studies and immerse themselves in direct service. The NCCM will be one of the community-based service partnerships that allow students to explore issues surrounding childhood STEM education, educational access, and exposure to STEM.

Recruiting college students to engage in outreach can be challenging; identifying interested students, likely based on their own early experiences, is essential. The Living Learning Communities (LLC) offer first-year college students with similar interests the opportunity to live together and participate in programs that cater to their academic, social, and personal needs. In a study with first- and second-year students, Hurtado et al. (2020) found that LLCs have a positive

influence on “collaborative learning, reflective and integrative learning, perceptions of a positive campus environment, perceived learning gains, and student–faculty interaction” (p.15).

CU offers numerous LLCs, some focused on hobbies and others more academically aligned with majors. A FIRST (For Inspiration and Recognition of Science and Technology) Robotics LLC was established in 2009 to engage both first- and second-year students who are interested in robotics and want to give back through service to community programs. This robotics-oriented LLC builds students’ 21st century professional skills (Bellanca & Brandt, 2010) through their participation in hands-on activities and local K-12 mentorship and by assisting with the annual regional FIRST competitions. More broadly, in 2019, CU established a STEM Ed LLC, designed for students interested in supporting the local North Country communities through mentoring and teaching. Opportunities are provided for CU students to work with local K-12 students and teachers through a wide range of STEM enrichment activities, which are discussed in this paper. CU students regularly help faculty run hands-on workshops and camps for local students throughout the year, provide after-school tutoring, and coach students in engineering challenges. These STEM-focused LLCs recruit students in their first year, and while some are relatively new, many continue to volunteer and engage in K-12 outreach activities in subsequent years.

Competitions and Challenges

Design challenges are a popular mechanism to engage and excite students in STEM studies and careers (David & Willenbrock, 1988; Elizondo et al., 2010; Kulturel-Konak, 2021; Mejia et al., 2019; Mentzer, 2011; Sadler et al., 2000; Van Haneghan et al., 2015; Zogaj et al., 2012). These programs provide authentic learning experiences that integrate STEM disciplines as participants work mostly in teams to solve real-world problems. Competitions can vary broadly – ranging from the traditional design-and-build model to IT and programming (e.g., ‘hackathons’ [Kulturel-Konak, 2021]) and even include ideas competitions for developing new procedures, strategies, or even small businesses (Zogaj et al., 2012). Design challenges have improved student engagement and motivation, feelings of self-efficacy, and concept retention (Mentzer, 2011; Lesseig et al., 2016; Mejia et al., 2019). They also allow students to develop important 21st century professional skills (Bellanca & Brandt, 2010) that will prepare them for today’s STEM careers, such as collaboration, communication, responsibility/accountability, decision-making, inquiry, and creative problem-solving. Additionally, competitions that expose the ‘human side’ of STEM, by emphasizing the social and ethical implications of STEM and the potential for creating societal good, appeal particularly to females and other underrepresented minority groups, providing an important avenue for engaging and supporting a more diverse group of students (Busch-Vishniac & Jarosz 2004; Godwin & Potyin, 2015; Kilgore et al., 2007).

The Institute for STEM Education supports a variety of STEM-related competitions and challenges that engage students at various levels, pre-college through graduate school, only a few of which are included in Figure 1. Several competitions are embedded in other programs; for example, CU-STEP also runs Game-on (a video game design challenge), No Limits (a roller coaster simulation challenge), POW (a STEM problem of the week challenge), and model roller coaster design challenge based on the national competition American Association of Physics Teachers. A few programs are described below that strongly support the rural K-12 partners shown in Figure 1: STEM QuESTS Challenge, Clarkson Discovery Challenge (CDC), CDC-

Space, and FIRST Robotics. FIRST and CDC-Space are based on national competitions, while CDC and STEM QuESTS were created by faculty at CU.

STEM QuESTS Challenge (Questions that Explore STEM for Teachers and Students) offers an alternative to the design and build, IT, or innovative product endpoint at the heart of most design challenges. Developed in 2021, the challenge invites CU students to create engaging STEM curricula to entice pre-college students to pursue STEM studies and careers. Students are asked to ‘think back to before college’ and consider what inspired them to choose their major and career pathway and then use that inspiration to create an educational experience, which could be a lesson, a set of lessons, or a module that could be incorporated into a middle or high school classroom. The lesson(s) should be unique and innovative, hands-on, interdisciplinary, or cross-disciplinary, and engage students in inquiry and active learning. Teams pitch their ideas in a 90-second Flipgrid video. The videos are used to evaluate entries and select four finalist teams. Each finalist team is assigned a mentor, an in-service or pre-service STEM teacher, or faculty from CU’s STEM Institute, to assist them with seeing their projects through to fruition. Students and mentors work together to develop their ideas into workable lesson plans tied to the NYS education standards. Final lesson plans, supporting resources, and recorded presentations geared toward teachers who might use their materials are submitted for evaluation and formal presentation to an audience composed of judges and members of the campus community and the general public.

Since its inception, the STEM QuESTS Challenge has engaged 48 undergraduate and graduate students from a range of STEM disciplines, including mathematics, chemistry, physics, computer science, and various engineering disciplines. Overall, the male-to-female gender ratio was approximately 50%, far higher than the percentage of females university-wide, 30%. Lessons touched on a wide range of topics, as shown by the examples in Table 1. All submissions have been very high quality. One of the 2021 judges, a science teacher from a local school district, commented about the four finalist entries: “I would use any of these in my classroom.” Several 2021 lessons have been used as part of class curricula or in after-school programs, such as CU-STEP described above. Student learning outcomes have been assessed for the Food-to-Energy lessons with simple pre-/post- and post-only online surveys. Among the 26 NYSED participants who responded to a simple post-survey, 21 students fully or partially saw connections between the lessons and things they learned in the classroom.

Clarkson University FIRST (For Inspiration and Recognition of Science and Technology) Robotics Outreach was established in the late 1990’s to provide local educators and students interested in robotics with professional development and an outlet to showcase their skills through friendly and collaborative competition. FIRST is a global robotics community, engaging PK-12 (ages 4-18) students in exciting, mentor-based research and robotics programs (www.firstinspires.org). There are three program levels within FIRST: FIRST LEGO League (FLL) for grades PK-8, FIRST Tech Challenge (FTC) for grades 7-12, and FIRST Robotics Competition (FRC) for grades 9-12. As a result of CU FIRST programs’ success, two regional FIRST competitions annually are hosted at the CU campus. Winners of these events advance to compete nationally in the FIRST Championship. Additionally, CU sponsors one FLL Explore Showcase hosted annually at a local school district. Table 2 illustrates each FIRST program and targeted grade level.

Table 1*Sample STEM QuESTS Entries, 2021 & 2022*

Lesson	Description
The Mathematics of Cancer	Various lessons that apply mathematics concepts and modeling to cancer research tumor growth
Ice Cream Chemistry	Students focus on the science and chemistry of ice cream making, integrating many STEM concepts
Food-to-Energy	A problem-solving module with lessons focusing on recovering resources from food waste
Whiteface Mountain Earth Science	Virtual field trip to Whiteface Atmospheric Science Research Center, accompanied with various hands-on STEM lessons
Positive Altitude - Mechanics of Flight	Students build model airplanes and learn mechanics of flight.
Pathfinders - All about Light	Students experiment with prisms to learn about the light spectrum.
Aquaponics	Students construct and operate an aquaponics system. They learn symbiosis between plants and fish, system management, and sustainability.
Physical Block Based Coding	Students create physical puzzle-like block pieces connected to simulate coding.

Table 2*FIRST (For Inspiration and Recognition of Science and Technology) Robotics Programs supported by Clarkson University*

FIRST Program	Grade Level	Supported within CU Robotics Outreach
FIRST LEGO League Discover	PK - 1	
FIRST LEGO League Explore	2 - 4	X
FIRST LEGO League Challenge	4 - 8	X
FIRST Tech Challenge	7 - 12	X
FIRST Robotics Competition	9 - 12	X

Institutional commitment to the FIRST Robotics program runs deep. The initiative is supported by a network of volunteers, educators, CU faculty/staff/students, and sponsors, who

mentor teams using the FIRST Core Values (Discovery, Innovation, Impact, Inclusion, Teamwork, and Fun) to conduct research, design, build, test, improve, and present their solutions. Currently housed within the Institute for STEM Education, one faculty member's teaching load is assigned to administering the CU FIRST Robotic Outreach program. One outcome of this partnership was the creation of regional FIRST teams that have grown from supporting two school districts, which represented one FRC team, to supporting over 20 school districts consisting of 80 plus teams. CU also provides scholarships to high school seniors involved in FIRST.

Clarkson Discovery Challenge (CDC) is part of the programming associated with CU-STEP described above but shared here for its unique contributions to providing an authentic STEM Challenge experience. CDC participants select a research topic and work with CU students and faculty to collect data, test their hypotheses, and present a poster at an annual local showcase. The top teams from the local competition compete in a statewide student conference annually with other STEP programs from across NYS. Winning a spot at the Statewide Student Conference is a milestone for the program. All participants in CU-STEP struggle with poverty. To this end, the conference is an unforgettable experience for students, many of whom rarely, if ever, leave Northern NYS. Roughly 500 students from across the state come together in Albany, the capital of NYS, and are immersed in a completely different setting compared to their rural home region. The conference is student-focused with workshops on academic success, self-care, college preparation, and STEM enrichment. Social events include a dance party and banquet with a motivational speaker focused on successful STEM pathways. Clarkson's CU-STEP students have won multiple trophies over the years for their research projects.

At the heart of CDC is student engagement in authentic research, and all participants benefit regardless of going to the conference. CDC typically kicks off in September, but brainstorming and research activities take place year-round. Students learn about the scientific method and participate in an immersive workshop that provides an example of how research is conducted. Students work with their teacher coaches and CU graduate student fellows to choose a topic and design their research methodology. Over the course of several months, students carry out their research. They eventually draft a formal abstract and design their poster. A detailed rubric helps guide them and prepares them for answering questions that may be asked during judging. The CDC experience builds a range of transferable skills including data literacy, technical communication (oral and written), collaboration, interdisciplinary problem solving, and most importantly self-confidence.

Clarkson Discovery Challenge – Space (CDC-Space) is an extension of CDC that focuses on microgravity. This new (one-year old) project uniquely combines aspects of competition and outreach with the K-12 rural school community, with teams competing to send their experiment to the International Space Station (ISS). CDC-Space is part of a national competition, organized through the Student Spaceflight Experiments Program (SSEP), which is part of the National Center for Earth and Space Science Education in the U.S., and the Arthur C. Clarke Institute for Space Education internationally. The competition is enabled through a strategic partnership with Nanoracks, LLC, which is working with the National Aeronautics and Space Association (NASA) under a Space Act Agreement as part of the utilization of the International Space Station (ISS) as a national laboratory.

In this first DC-Space competition, 200 middle and high school students from rural school districts learned about microgravity. Through support from CU faculty and students, all students created their own experiments to test the effects of microgravity both on earth and in space. They learned about experimental design and proposal writing through first-hand participation in a real-world project that was connected to the SSEP competition. While it was challenging for many students, they learned about the true nature of science through first-hand experience. For example, they learned that science is a process that is not always done in a neat, stepwise fashion. They also learned to work within constraints; their experiment was required to fit within a certain size tube and could only be manipulated by the astronauts for a limited time over a certain number of days. The winning team from this first year of the competition designed an experiment to test the impact of microgravity on specific algae in space, with identical experiments conducted here on earth (by students) and on the ISS (by astronauts). The student team is invited to attend the launch of the experiment in Cape Canaveral, FL, and also to present their findings at the Smithsonian National Air and Space Museum in Washington, DC. The high school science teacher who works with these rural students said:

The students were able to explore their own research ideas and get the satisfaction that they can be real scientists through experiments. They were empowered to put their thoughts on paper and perform their own research. Who knew that microgravity was a thing and is important in our daily lives? The experience will be something they will never forget. Some are already thinking of their proposal ideas for next year.

All students who submitted proposals and participated in the competition engaged in scientific work. They all experienced the amount of writing involved and the challenges of working within a set of tight constraints. Despite the challenging nature of the project, many students were engaged, felt competitive, and worked hard, hoping their proposal would be selected. CU faculty members helped as expert consultants to ensure the science was accurate. Students came to campus twice and completed the rest of the work virtually. This combination of in-person and virtual work is useful for supporting rural schools, where distances between school districts and the university, and among the school districts themselves, is often a challenge. The large geographic areas served by rural school districts contribute to transportation difficulties. The bus rides are longer, students return home late, and there are fewer transportation modes. However, the more recent experience of working online through the pandemic has supported students by enabling them to work together without having to travel. This is another example of how the relationship between a university and a K-12 school system in a rural area can be enhanced with creative programming solutions.

University Programming/Commitment to Education

In 2019 CU was awarded a Noyce Grant for their Teacher Preparation Program from the National Science Foundation, with the goal of preparing high-achieving math and science students to work in high-need schools. The program initially intended to compare the preparation of pre-service teachers for rural versus urban schools; however, many scholars were choosing to work in rural areas. As a result, the partnership team is faced with a new question: is preparing rural teachers becoming a large part of the identity of this program? Through this work, CU has joined 14 other universities interested in understanding how to recruit and retain science and math teachers to work in rural schools.

CU students who are interested in becoming STEM teachers have many opportunities and support to visit classrooms and participate in field observations. The University is committed to supporting STEM Education, as shown through the recently established Institute for STEM Education as well as other efforts such as allowing STEM outreach to be considered as part of a faculty member's teaching load. These examples demonstrate the University's commitment to actionable support, without which the multiple partnership activities described here would not be sustainable.

Recommendations

This article shares experiences and puts forth ideas on how other universities, particularly STEM-focused rural universities, can partner with local school districts to enhance STEM teaching and learning opportunities. A major challenge in rural education involves inequitable opportunities in STEM. The partnerships described above are critical to deeper learning in STEM; at the same time, they directly broaden participation in STEM by engaging more students who are socioeconomically disadvantaged. These partnerships respond to national calls for improving and diversifying the STEM workforce by supporting and promoting programs that broaden participation and are shown to be effective.

Key to the success of these programs is a commitment from all stakeholders – university leadership, faculty, students, organizations, and offices as well as partnering school district leaders, teachers, students, and parents. Time and energy are the most valuable resources, but funding enables programs to grow and thrive. Of utmost importance is a commitment from leadership at the university and school district levels. If faculty believe that outreach is valued, for example towards tenure and promotion, they are more likely to engage more deeply in the development of large-scale activities. If school district leaders' input is valued, they feel buy-in. If teachers are supported for their time and efforts by building leaders, they will be willing to take risks and try new experiences in and outside of their classrooms. Support from university and school district leaders will ensure that programs are sustained from year to year. Below are some final thoughts for building community partnerships between a STEM university and rural school districts:

1. Seek out people on campus who are invested in building partnerships with the local community, in particular faculty and campus community members who are parents and understand the challenges on a personal level.
2. Establish a dedicated position at the University for someone (e.g., a retired school teacher, superintendent, building leader) who can help establish relationships with school districts, get buy-in, and assist with curriculum design so it is delivered at the appropriate level.
3. Persistently seek funding (e.g., the CU-STEP grant took three tries; the Noyce grant took two tries).
4. For developing programs or partnerships, start small to develop a proof of concept and then grow out ideas as you apply for funding – consider local agencies/industries, state programs, and national funds.

5. Learn about poverty and rural challenges – the local K-12 students are likely different from the ones you have in your college classrooms; learn and understand the local community.
6. Garner support from offices on campus – send out a campus-wide call for help; you may be surprised by who wants to get involved.
7. Advertise broadly for college student helpers--they often love to volunteer.
8. Showcase student engagement and teachers' commitments in local papers, news channels, social media, and events to spread the word of the important and impactful work you are doing – this can help get buy-in and support from both the school district and the families involved.

These recommendations are based on years of experience, mainly from a handful of faculty who helped create these networks and cultivated their relationships over the years. Like any geographic area, rurality has its own unique challenges. However, with strong institutional leadership, a sense of shared ownership and accountability, and culturally relevant programming, a university–community partnership can be established, broaden participation in STEM, and ultimately narrow the inequities that exist in rural communities.

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About the Authors

Katie Kavanagh, PhD, is the director of the Institute for STEM Education and a math professor at Clarkson University. Dr. Kavanagh's research interests include numerical analysis, computational mathematics, non-linear equations, and many applications of mathematics. She also has an extensive background in creating and teaching professional development for K-12 STEM teachers.

Jan DeWaters, PhD, is an associate professor in the Institute for STEM Education with a joint appointment in the School of Engineering at Clarkson University and teaches classes in both areas. Her research focuses on developing and assessing effective, inclusive teaching and learning in various settings. An environmental engineer by training, Dr. DeWaters's work typically integrates environmental topics such as energy and climate into STEM settings.

Seema Rivera, PhD, is an associate professor of science education at Clarkson University. Her research interests include STEM Teacher preparation and the intersection of diversity, equity, and inclusion with STEM both in K12 classrooms and higher education. She works with STEM preservice teachers and is the principal investigator for the Noyce Scholar program at Clarkson. Dr. Rivera is a former chemistry teacher.

Melissa Carole Richards, PhD, is an assistant professor and director of the Horizons Programs and Robotics Outreach Programs with the Institute for STEM Education at Clarkson University. She is committed to fostering greater diversity, equity, inclusion, and belonging in academia as a whole and engineering specifically. She holds an Associate of Science in Engineering Science from Nassau Community College. In addition, she earned a Bachelor of Science in Mechanical Engineering with a minor in mathematics and a Master of Science and Doctorate of Philosophy in Mechanical Engineering, all from Clarkson University. Her research interests are in theoretical rock mechanics and STEM education.

Mike Ramsdell, PhD, is an associate professor of physics at Clarkson University; his research interests include physics education research, laboratory curriculum development, and design. Dr. Ramsdell has focused on implementing and assessing the physics team design program for the calculus-based introductory Mechanics, Electricity, and Magnetism courses. Dr. Ramsdell also has an extensive background in developing and running STEM professional development and STEM camps for middle and high school students.

Ben Galluzzo, PhD, is an associate professor of mathematics at Clarkson University. Dr. Galluzzo's area of research concentrates on developing new strategies and best practices for bringing innovation and active learning into K-16 STEM classrooms, with a particular emphasis on mathematical modeling. Dr. Galluzzo also has an extensive background in creating and teaching professional development for K-12 STEM teachers.

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