Chapter 11

From Curiosity to Discovery: Promoting Student STEM Research in Rural High Schools

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Chapter Highlights

This chapter examines how authentic STEM research experiences can be designed and sustained to support rural high school students through targeted mentoring, place-based learning, and community partnerships.

- Rural STEM Challenges: Rural students face persistent barriers such as limited access to advanced STEM courses, mentors, technology, and funding, which restrict participation in high-quality STEM research.
- NC STEM Research Academy Model: The chapter introduces the NC STEM Research Academy as a scalable framework to increase rural student participation in STEM research and engineering design.
- Teacher-Led Mentorship: Rural teachers are positioned as key facilitators, with professional development, stipends, and sustained support strengthening teacher–student research partnerships.
- Place-Based & Funds of Knowledge: Student projects are grounded in local community needs, place-based contexts, and family knowledge, enabling meaningful and resource-efficient research.
- Flexible & Virtual Mentoring: The use of virtual mentoring, near-peer support, and local materials helps overcome geographic isolation and infrastructure limitations.

To Cite This Chapter:

Wickliff, A. (2025). From curiosity to discovery: Promoting student STEM research in rural high schools. In M. T. Hebebci (Ed.), *Innovative Practices in STEM Education: Emerging Technologies, Pedagogies and Learning Models* (281-299). ISRES Publishing

Introduction

Conducting STEM research is useful for all students but an especially valuable one for rural high school students. According to Why Rural Matters (2023) there are over 7 million students enrolled in rural school districts representing 15.7% of all public-school students in the United States and one in seven of these live below the poverty line. Rural students have many challenges that may hinder their academic success, growth and opportunities in STEM. These challenges can include limited access to advanced STEM courses in math, science, engineering, and computer science, fewer teachers qualified to teach in STEM content areas, limited access to technology, fewer extracurricular programs in STEM, fewer community-STEM based resources, and less financial support (Why Rural Matters, 2023; De Mars et al., 2022; Grimes et al., 2019; Marksbury, 2017). Finally, in many rural districts one third or more of students do not have internet connectivity at home (National Center for Education Statistics, 2023). These limitations restrict high school students' access to high-quality STEM education and workforce development in rural areas. By engaging in STEM research, students can access local resources, mentors, and experiences that might otherwise be overlooked in rural areas. Performing STEM research gives rural students the opportunity to build essential skills, foster critical thinking, strengthen academic confidence, and helps them to consider access to high-demand jobs and higher education.

Why a NC STEM Research Academy?

According to Public Schools First NC (2025), more than one in three students attend school in a rural district and North Carolina has the second largest rural student population in the US, after Texas. Eighty of North Carolina's 100 counties are predominately rural and 42 percent of schools in the state are rural. North Carolina is one of the US states where rural students graduate high school at a lower rate than their non-rural peers. The challenge for engaging rural high school students in STEM research is two-fold. First, students must be convinced the effort is worthwhile and second, students must be provided with the resources and encouragement to succeed. Our project partners established a high school NC STEM Research Academy to increase the pipeline of diverse students engaged in STEM research in rural school districts in eastern and western NC. We have worked together for many years and came to realize that a large percentage of students were not being introduced to STEM research in high school. Facilitating high quality student research is a challenge in rural areas with limited access to community resources, materials and mentors.

Originally, we conceived the idea of a NC STEM Research Academy to develop grant proposals to state and federal agencies with a long history of supporting K-12 STEM research competitions in NC. With over 15 years of experience, we saw the same set of high school students with STEM research projects often competed against each other at the yearly events.

These students were typically not ethnically diverse and, for the most part, came from the same schools, geographically located in the same major urban areas of the state. In order to diversify and increase the number of students from across North Carolina, the Academy partners targeted schools located in the coastal, eastern part of North Carolina and the mountains, western area of North Carolina. Both areas are classified rural and have high poverty populations.

Because of the project partner experience in working with NC rural teachers and students, we knew from the outset the following program parameters:

1. The key to working with students is identifying and working with a teacher who will in turn support the student.
2. Rural teachers who are willing to work with students conducting STEM research typically have little to no experience with research themselves.
3. Most rural students are new to research and have little to no experience with either the scientific method or engineering design process.
4. Student STEM research is not explicitly listed in the state science or math standards, and so student work needs to be completed during extra-curricular hours.
5. There are fewer resources, financial, STEM mentors, STEM businesses, etc. available to students in rural areas.

Given these conditions, we designed the NC STEM Research Academy. The program began in 2017 with more than fifty students, and ten teachers total from eastern and western North Carolina. The project partners included university STEM outreach education specialists from two universities, two high school teachers, a school district administrator, and a statewide non-profit foundation director. The participants of the Academy included both rural teachers and students. Initially, funding was provided by the US Army exclusively. The initial funding was a modest amount and was awarded as a pilot study. The award was for one year at $25,000 and was later increased to $50,000 per year. However, when the Army funded ended after five years other program partners contributed to support the program for two reasons. The first reason is that the program expenses were not costly, and the second more compelling reason was that the program partners recognized the success of the program. Rural teachers and students completed research projects and successfully competed in STEM events against daunting odds including crippling snowstorms, massive hurricanes, and school relocation.

The program expenses initially covered educator stipends to encourage their participation, refreshments for students to meet on the weekend, and travel expenses for university and master teacher mentors. The other budgeted expense built into the program was for research materials and supplies. Program partners assumed that students would need funding to support their research ideas, especially if their research work was to be competitive in the statewide STEM competitions typically populated by students who have been mentored at university labs or advanced STEM schools. Project partners anticipated the cost of renting lab space, paying for use of expensive analytical equipment, chemicals, glassware, rare metals, etc. However, what we did not realize is the resourcefulness of the students and the fact that their ideas for research focused on meeting a local or community need that did not necessarily equate to a need to purchase expensive supplies and materials or rent or use expensive equipment. Even when we offered to purchase new supplies for projects students often refused and found items readily available from family or recycled materials rather than purchase new materials. For example, one student in the western North Carolina mountains wanted to research windcatchers as a way to provide air conditioning without increasing energy costs. He was interested in researching this passive cooling system because of the increasing number of days of higher temperature due to climate change. Currently most homes in western North Carolina do not have central air conditioning. Project partners offered to purchase new piping (duct work) for his experimental set up in an outbuilding on his property, but his father had found a home that had been remodeled, and the piping (duct work) was available for free reuse, so the student refused our offer. This is just one example of many of how our offers to purchase supplies were often turned away by students who found what they needed from their peers, family, and others in their rural communities. This is very much a benefit of rural life either in the mountains or on the coast of North Carolina.

Table 1. NC STEM Research Academy Schedule

Assignment	Assignment Description (Note: Students should have at least 12 weeks to do their projects)	Meetings
Teacher Training	Professional Development Training -Research Methodology and Working with Students	Overview In Person East and West Cohorts
Selection & Permission	AEOP Teachers Announce and Select Students for Program. Students must sign participation contract.	Completed at School
Topic Selection	Students need to select a topic area and propose a researchable question or engineering design project.	Project Partners meet virtually with Teachers prior to Student Meeting Virtual 9-Noon, Saturday
Research Plan	Mandatory for ALL Students.	Submitted to Project Partners
Research Paper & Poster Content	Meeting to discuss research paper format and content that can and should be used for Poster content. Review sample papers and posters from past STEM competition.	Project Partners meet virtually with Teachers afterschool. Student Meeting Virtual 9-Noon, Saturday
Experimental Design Materials & Procedures	An explanation of Variables, Independent, Dependent, Controls. A detailed list of the materials that will be used to conduct the experiment and must be submitted to project partners for purchase.	Project Partners meet virtually with Teachers afterschool. Student Meeting Virtual 9-Noon, Saturday
Data Overview	Students NEED to provide good data analysis for their projects. At a minimum mean, median, mode, and standard deviation need to be provided and discussed. Students should consider using inferential statistics to support their research questions.	Project Partners meet virtually with Teachers afterschool. Meet with Students In-Person East and West Cohorts.
Conducting the Experiment	There should be a minimum of two weeks to allow the students to do multiple runs of their experiments. Minimum Trials: 5 runs of experiment/trials. Engineering Design: List Test Parameters	Completed with Teacher Facilitation
Data Analysis & Graphs	The analysis of the experimental data. A summary of the findings of the experiment or testing engineering design.	Project Partners meet virtually with Teachers afterschool. Student Meeting Virtual 9-Noon, Saturday
Final Report/ Posters	A report that collects all the above written assignments with an explanation of results. Preparation of project abstract.	Completed with Teacher Facilitation

Display Board	Draft Project Board and Presentations	In-person Joint Meeting East and West Cohorts
STEM Competitions	Held Throughout Spring Academic Semester	

Project partners began with a two-day teacher training for teachers to explain the goals and learning objectives of the Academy, to demonstrate activities, and to share program materials for student participation. The Academy begins at the start of each academic year in late August or early September and students work through mid-February to be prepared to present in a statewide STEM competitions held throughout the Spring. Project partners mentor formally between eight to ten days during the Academy. Prior to Covid pandemic, mentoring was done onsite and in person but post-Covid, mentoring was primarily completed virtually. The format of the Academy sequentially follows the steps of scientific research or engineering design. Many teachers have stayed with the program for eight years and know what research activities the students need to complete in what progression to prepare them for the STEM research competitions. Table 1 provides the schedule of the NC STEM Academy Research tasks.

Why is the NC STEM Research Academy Successful?

The key to working with rural students is identifying and working with a teacher who will in turn support students. The essential first step to a successful STEM research program and the success of the NC STEM Academy is locating rural teachers who want to participate. The initial stipend of $800.00 helped entice teacher participation. Each teacher was expected to work with four to five students facilitating research work. Teachers were expected to attend all Academy virtual and in-person meetings during the academic year. What project partners know is that rural students prefer to work with people they know and do not prefer to work with strangers especially from outside their communities. Identifying a teacher research partner for students is critical. However, a strong teacher advocate who supports students is a universal benefit in high school regardless of geographic location. High school students, like all students, appreciate and benefit from strong, supportive teachers. Students perform better and are motivated to learn when positively encouraged and taught by a caring, supportive educator. Rural teachers know their students and families and are visible and well-known in their community. Typically, the rural school is one of the largest employers in the community and a teacher most likely knows the parents and has probably taught siblings of students. Knowing this, project partners sought out rural teachers interested in facilitating research projects for students in their content area, mainly in biology and environmental science.

The teachers would be provided with a small stipend and training and sustained with support by project partners. Because student STEM research is not a required in the NC course of study for either science or math, students would need to work on their research projects after school.

Therefore, participating teachers would have to understand that they would need to dedicate time after school to the NC STEM Academy. Project partners worked with school district personnel in the western and eastern NC areas to identify teachers who would be willing to participate.

According to The National Academies of Sciences, Engineering, and Medicine; Education, 2024*,* rural teachers tend to be less qualified in STEM because they are generally paid less, and locations are geographically less desirable. In addition, rural teachers who are willing to work with students conducting STEM research typically have little to no experience with research themselves. Project partners expected to identify teachers and knew that many would not stay with the program. In total, more than 25 teachers have participated in the Academy and today we have five teachers who have continued with the program since its inception. Of these five teachers, two worked outside the classroom prior to becoming teachers. One educator worked as a biomedical laboratory technician, and another worked as a water quality scientist with the U.S. Environmental Protection Agency. These STEM experiences enabled these educators to serve as role models to the other educators. They reinforce good research practice instruction with the teachers and help mentor all students during Academy meetings, in-person and virtual. Other teacher participants left the program due to family changes, school changes, and two teachers moved out of the state. The coastal area of North Carolina is home to military bases and so both teachers and students move in and out frequently due to reassignments.

The initial teacher training was held so project partners could overview the Academy goals and model the initial steps to conducting STEM research. It is essential to provide clear and concise goals for the educators. The NC STEM Academy initially met on Saturdays to model research instruction and activities for the teachers and students. The goal was to "train' the teacher and educate the students so that the teacher could then sustain the program year after year with minimal support from the project partners. Each Academy meeting was designed with the purpose of preparing a final research paper and poster for STEM competitions held throughout the spring in North Carolina. With this endpoint in mind, each Academy event included time spent with students and teacher participants reviewing, evaluating, and reporting on past competitive high school student posters. These artifacts included past high school student posters from various competitions from within the past three years that were national or state-winning posters and some that did not place. Academy participants met in groups to review the posters, and they used existing judging rubrics from the International Science and Engineering Fair (ISEF) or other competition rubrics to judge the posters. This process allowed them to learn the framework for and expectations of their research work for competitions. The students had an endpoint to work towards based on seeing finished research papers and posters prepared by other high school students. An example of an award winning poster is provided in Figure 1.

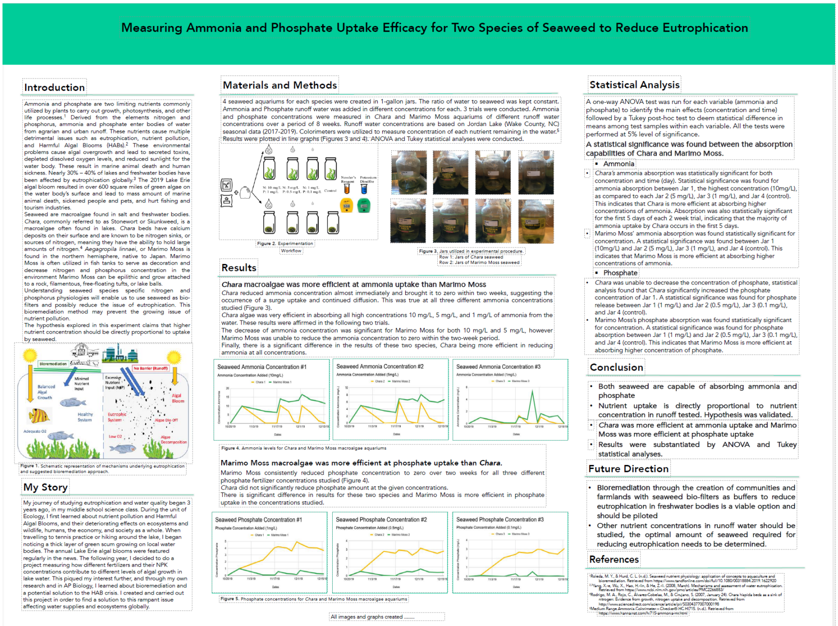

Figure 1. Sample High School Research Poster

One challenge of research for high school students is identifying a reasonable researchable question, hypothesis, or engineering problem statement. When surveyed at the end of each academic year, teacher participants listed that the most difficult challenge for them was facilitating students through their selection of a topic for research. Almost all rural students are new to research and have little to no experience with either the scientific method or engineering design process. One advantage for rural education is local rural or place-based knowledge of residents. Avery (2013) says that rural students who are engaged with their local environment and issues can make connections beyond their school environment directly impacting their community. The National Academies of Sciences, Engineering, and Medicine; Education (2024) suggests that STEM is inherent in rural communities, especially those tied to ”agriculture, coastal communities, and remote communities that rely on a subsistence economy (p. 18).” The STEM Academy students from western and eastern NC did make connections to their communities based on their rural places and knowledge. Rural areas are a great place for learning science and engineering with access to natural areas, work in agribusiness such as farming or fishing. Many rural students learn to develop engineering and science skills in their daily lives to solve problems and fix equipment in their daily work activities. This type of experiential learning increases students' knowledge and ability to achieve in STEM course work and to take on a STEM research project. Below is a table of project titles from student research projects from western and eastern rural NC students. It is just a sample of projects students have undertaken but it is clear the students understand their community context and want to be helpful or solve a problem that is local.

Another source of knowledge for rural students is their families with their accumulated wisdom, hands-on knowledge of jobs and careers, where they have lived, the history of a region, people, traditions, and cultural practices. The concept of "funds of knowledge" by Luis Moll (2005) is that people have knowledge learned from their life experiences. The most direct way of accessing students' funds of knowledge is to get to know as much as possible about the student. A good start is to find out what the student might be interested in researching in the context of their family and community. See Figure 2.

Table 2. List of Student Research Projects

Name	Research Project Title	School
Student A	Impacts on Local Air Quality from Personal Burn Barrells	Onslow Early College High School
Student B	Developing a Biodegradable Water Bubble Solution to Reduce Plastic Water Bottle Waste	Onslow Early College High School
Student C	*The Effects of Various Plants on Fertilizer Runoff*	Onslow Early College High School
Student D	ENO River Quality	Onslow Early College High School
Student E	The Cost Efficiency of Store Bought versus Home-Made Compost for Plant Growth	Northside High School
Student F	Cost Efficiency of Vertical Solar Panels	Onslow Early College High School
Student G	How Does Renaming a Military Base Affect Local Communities	Northside High School
Student H	The Impacts of Microplastics on Plant Growth and Soil Health	Onslow Early College High School
Student I	*Quantitative Analysis of the Effects of Agricultural Absorption Rates on Greenhouse Gas Pollutant*	Avery High School
Student J	Using Coding and Condensed Microphones to Determine the Location of a School Shooter	Avery High School
Student K	Mycofiltration Within Bacterially Polluted Waters	Avery High School
Student L	Revolutionizing Kudzu into a Sustainable Bioplastic	Watagua High School
Student M	Utilizing Lagenidium giganteum to Eradicate Mosquito Larvae	Watagua High School

STEM Research Project Brainstorming Worksheet Name:

I. Brainstorming List (Places, Natural Areas, People, Events) Who do you know? What do they do? How can they help? What tools or things do they have they can share with you?

II. Two general areas of STEM interest:

1.	2.

Two specific problems for each area of interest:

1A	2A
1B	2B

III. Brainstorming Questions Now choose one problem from above. Answer the questions below only for the problem of greatest interest from above.

1. **What materials are readily available to me for conducting experiments or designing a model or prototype on this topic?**
2. **How does the topic act or respond? OR what type(s) of behavior or performance will it exhibit?**
3. **What types of materials could be used to cause this topic to react or show change?**
4. **How can you measure a response or change?**

Figure 2. STEM Research Project Brainstorming

We learned a great deal about the participating students when they completed the STEM brainstorming worksheet (Figure 2). We know these students have strong, extended families in the area and that they rely on their family members, community contacts, and friends for information and resources rather than relying on outside assistance. We were able to identify STEM resources and STEM expertise that other students' family members willingly offered to provide other students. Academy members, both project partners and teachers, realized that we would not have many of the research projects from high-achieving students we typically see from mentored research labs, but we would have good, strong well conducted science and engineering projects from students who cared about and are connected to their work. The measure of success was not winning the STEM competitions but rather knowing students understood and appreciated what they gained from the research process. Most Academy students participated throughout high school until graduation and so many of the alumni have gone on to continue STEM research in their undergraduate studies. They have gone on to attend Columbia University, University of South Carolina, North Carolina State University, University of North Carolina, and more. These students have told us that their experience in the NC STEM Academy gave them the confidence to pursue STEM coursework in engineering, bioengineering, medicine, at the undergraduate level.

There were a few students that were unable to participate not because of interest but because of life circumstances. One student did not have the time or means to attend the after-school sessions because they needed to stay at home to care for their younger siblings. Both their parents work as migrant farm workers, and one parent had recently had a bad accident using farm machinery and could not work nor care for the younger siblings. Another student was unable to participate because the parents who did not speak English as a first language were anxious about traveling to participate in events outside of their community.

Mentoring Rural Students

Mentoring rural students in science research requires both creativity and flexibility. By leveraging local expertise, identifying less traditional mentors, and creating opportunities for students to refine their protocols and present their work publicly, educators can make authentic science accessible outside of large urban centers. Approaches such as pairing students with local scientists, connecting them to near peers, and offering structured feedback through showcases empower rural youth to see themselves as capable contributors to scientific inquiry.

Equally important are new approaches that use technology to bridge geographic isolation. Virtual mentoring, remote lab access, and digital collaboration platforms allow students to interact with experts, refine their projects, and receive ongoing guidance. These strategies broaden access to mentorship networks and ensure that rural students are not left behind in developing 21st-century scientific skills. Ultimately, building sustainable mentoring systems requires partnerships among schools, universities, local communities, and professional organizations. By widening the definition of who can serve as a mentor, whether a teacher, scientist, college student, or industry professional, rural students can access multiple pathways to experience authentic research collaboration. These connections foster not only scientific understanding but also confidence, resilience, and a sense of belonging in a STEM community.

Project partners initially drove to western and eastern NC, each trip several hours to meet with teachers and students. These Academy meetings took place on Saturdays and were packed with activities, discussions, and group work. The effort required time and expense for the four to five project partners, travel expenses, Academy expenses, snacks and lunch for the students in addition to the pre-planning for each meeting. When the Covid pandemic hit, partners had to pivot quickly to an online platform to complete the year. It quickly became apparent that the teachers were more than capable of sustaining the program onsite while project partners could join virtually to provide group activities, discussion, and mentoring. Students meet with partners virtually at assigned times who give them feedback at all stages of their research journey.

Community Resources for Rural Students

Community-based programs can draw on local expertise and environmental features, such as farms, forests, rivers, beaches, and mountains to create meaningful learning experiences (Avery, 2013). This local context helps students see the relevance of science and engineering to their own lives builds connections to place and a sense of belonging to community. Because of the nature of STEM learning in rural areas, STEM education can occur in a variety of environments, from classrooms to museums, zoos, online, the home, parks, gardens, and other natural areas. In eastern North Carolina, a main resource for students is the local military base. Not only are there STEM personnel, engineers, information technology, etc. but there are plenty of service industries off-base that students can connect with for information and assistance. The eastern NC student cohort also has access to coastal water research laboratories. These governmental and non-profit organizations study marine animals and water quality. In the western NC region of the state an important industry is ecotourism. Keeping water quality pristine, commercial land development is limited, and biodiversity is encouraged. This focus and the organizations, Soil and Water Conservation, Park and Recreation Department, etc. are all useful community organizations students can work with to collect data, review methodology, results and to share their findings and results.

Conclusion: Program Success & Implications

The NC STEM Academy demonstrates that rural students can engage in authentic research experiences when supported by dedicated teachers, mentors, and community partners. Program success rests on three central practices: (1) selecting partners who are committed to increasing rural student participation in STEM research and engineering design projects, (2) engaging rural students, teachers, school administration who will actively participate in STEM research opportunities, and (3) cultivating relationships with universities, businesses, and community groups to expand access to STEM mentoring, resources, internships, and funding partnerships. This work affirms Boyer's (2006) insight that effective rural education "offers a deep respect for rural life and honors the determination of residents to sustain rural communities. It's inherently interdisciplinary, project-based, and it builds on local resources and expertise" (p. 115).

The implications are clear: research-based, project-driven mentoring in rural areas is not only feasible but transferable. As Rural Education at a Glance (USDA Economic Research Service) shows, higher levels of educational attainment directly support stronger economic outcomes in rural areas. When rural schools invest in research they contribute to long-term community sustainability by preparing students for both higher education and the modern workforce.

- Sustaining and scaling this model requires intentional collaboration. Our model follows closely the criteria for educating a rural workforce suggested by the U.S. Department of Agriculture's Economic Research Service Rural schools (2017) and includes:
- **Using place-based education:** This connects research work with local resources, history, and the environment to explore real-world learning opportunities.
- **Establishing strong partnership between teacher and student researchers:** This promotes consolidation of resources, knowledge, and expertise.
- **Creating professional networks:** Partnerships among community business, industry and education allow rural teachers and students to develop mutually beneficial relationships.
- **Engage universities in "grow-your-own" initiatives**: This will strengthen the pipeline of rural educators and encourage students to pursue STEM careers
- **Partner with businesses and higher education institutions:** This provides an excellent directory for research mentoring and assistance.

By leveraging these strategies and resources, the NC STEM Academy model shows how rural schools can create sustainable pathways to STEM success. The result is not only stronger individual outcomes for students but also the revitalization of rural communities through education, workforce readiness, and innovation.

Program Success and Implications

The NC STEM Academy successfully engaged high school teachers and students in STEM research by 1) Choosing individuals from local schools and the community strongly committed engaging in research and engineering design projects; 2) Working with rural students, teachers, families, community members, and organizations so pipelines to STEM higher education and career pathways remain open to rural students; and 3) Pursuing and cultivating relations with various organizations to provide rural students with formal experiences in STEM through shared resources, mentoring, and internship

Resources*:* Implementation Guide: Starting a Rural STEM Research Program

For educators and communities interested in replicating the NC STEM Academy model, the following steps provide a practical roadmap.

- Needs Assessment: What are the local strengths, what gaps exist (e.g. lab equipment, mentor access, teacher training), what are anticipated costs?
- Stakeholder Engagement: Involve students, teachers, families, local scientists/industry from the beginning.
- Pilot Project: Start with a small research project (e.g. local environmental science, agricultural research, citizen science) to pilot program activities, mentor connections, student interest.
- Resource Mapping: What community colleges, business, industry, governmental organizations are within reach? Are there online platforms, virtual labs if physical labs are too far or expensive?
- Evaluation and Feedback: Build in ways to assess what works, collect feedback, refine protocols.
- Scaling & Funding Strategy: Once pilot is successful, seek funding, formalize partnerships, maybe build a pipeline (e.g. mentorship → summer research → showcase → further opportunities).

Best Practices for Program Success in Rural Communities

- Project-based, place-based learning: Anchoring research projects in the local environment (ecology, agriculture, local issues) helps engage students and draw on local expertise.
- Virtual mentorship / collaboration: Use of remote scientists, online lab simulations, virtual research tools so that rural students aren't limited by lack of local resources.
- Partnerships: With universities, industry, extension services, museums, community organizations. These can provide mentor help, provide equipment and sites for fieldwork.
- Teacher professional development: Model research process for teachers using inquiry-based methods, scientific research skills,

project management, data analysis etc.

- Local capacity building: Building from local knowledge (community practices), leveraging what is available (land, community, existing facilities).
- Sustainability planning: Securing multi-year funding, integrating with school district priorities, involving families and community, embedding programs so they survive beyond individual champions.

By following these steps, rural schools can adapt the NC STEM Academy framework to their own contexts, creating sustainable pathways to STEM success and ensuring that students are prepared for both higher education and the modern workforce.

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INNOVATIVE PRACTICES IN STEM EDUCATION

Emerging Technologies, Pedagogies and Learning Models

Innovative Practices in STEM Education: Emerging Technologies, Pedagogies and Learning Models examines how contemporary pedagogical approaches and emerging technologies can be effectively integrated to design meaningful, equitable, and sustainable STEM learning environments. This edited volume moves beyond technology-driven innovation by emphasizing the critical role of theory-informed pedagogy, curriculum design, and assessment in advancing STEM education. Drawing on diverse frameworks such as inquiry- and problem-based learning, computational thinking, gamification, variation theory, integrative STEM, and TPACK, the book illustrates how innovative practices support deep conceptual understanding, creativity, and collaboration across STEM disciplines. Mathematics is positioned as a unifying discipline that connects science, technology, and engineering through modelling and problem solving. With a strong focus on implementation and equity, the volume presents international case studies and research-based examples from face-to-face, hybrid, and virtual contexts, including rural and underserved settings. By critically examining emerging technologies—such as augmented reality, metaverse environments, open-source platforms, and game-based learning—alongside STEAM, entrepreneurship, and community-based initiatives, the book offers a comprehensive and practice-oriented perspective. Intended for researchers, educators, and policymakers, this volume provides an evidence-informed roadmap for developing coherent, inclusive, and future-ready STEM education practices.

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