Work in Progress: Place-based Engineering with Rural Schools: Investigating the SCience and ENgineering Inquiry Collaborative (SCENIC) in Colorado

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Background, Motivation and Purpose

The Colorado SCience and ENgineering Inquiry Collaborative for Rural K12 Outreach (SCENIC Colorado) is investigating an educational infrastructure for supporting engineering and science learning and identity formation as part of an outreach program with rural Colorado high schools. This research takes the rural context into careful consideration. While rural places are often described by their deficits (Reagan et al., 2019), this study operationalizes place-based pedagogy and the theoretical framework of rural cultural wealth (Crumb et al., 2022) to conceptualize and engage rural places from an asset-based perspective. We believe rural places can be rich environments for engineering and science learning. Therefore, we aspire to support high school students with the development of soil or air quality inquiry projects that are relevant to their local rural communities. Situated within a larger study on the SCENIC outreach program and its impact on student participation in and identification with engineering and science, this paper focuses more narrowly on place-based engineering with students in the rural context. The research questions are: What aspects of the outreach program's educational infrastructure enable place-based science and engineering inquiry? What aspects of place—their locality's history and culture—inform rural students' selection of environmental monitoring topics to investigate? How does conducting place-based environmental monitoring projects contribute to rural students' engineering and science identity development?

In the United States, rural settings are an under-researched (Lavalley, 2019) cultural context for education, even though approximately half of school districts, a third of schools, and a fifth of students in the United States are in rural areas (NCES, 2016). Rural students are underrepresented among college attendees, specifically among STEM (science, technology, engineering, math) majors (Saw & Agger, 2021). Furthermore, rural high schools include a larger population of students who are unprepared for engineering formation and may experience lower retention throughout an engineering pathway (DeUrquidi, 2019). Programs aimed at professional engineering formation among rural students may help close this gap. The cultural dimensions of how people learn and come to think of themselves as future engineers may differ for rural students, and among students in different rural contexts (Matusovich et al., 2017). Therefore, place-based education may be particularly impactful in rural settings (Shamah & Mactavish, 2009).

A key motivator for engaging in this project is to advance understanding of how to foster rural K-12 students' engineering formation and pathways. As in the rest of the nation, rural high schools in Colorado are underserved with respect to university outreach and engineering education. Research has documented that "rural students tend to lack opportunities to learn in STEM" (Saw & Agger, 2021, p. 595). One reason for this under-representation can be found in previous SCENIC assessment results indicating that almost half of the student population would be the first generation in their families to attend college. In response, SCENIC is providing university mentors to assist with high school student projects, answer questions about engineering as a career and serve as role models for students thinking of attending college

(Knight et al., 2019; Hinojosa, 2018).

In addition to mentorship, SCENIC also provides high quality environmental monitoring equipment to support engineering and science learning in rural communities. This is important because rural high schools often cannot afford quality laboratory equipment like university researchers use. While schools closer to universities might have access to these resources simply due to the privilege of proximity, the nature of geographic isolation for much of rural Colorado makes accessing university resources a challenge. SCENIC seeks to disrupt this inequity by providing a set of environmental monitors ("Pods") developed specifically for rural school partners, as well as the technical support for their operation and troubleshooting.

The environmental focus of SCENIC is well suited both to the engineering field and to rural students. The project occupies the intersection of environmental engineering and environmental science. The affinity between environmental engineering and environmental science is evident in the key professional societies such as the American Academy of Environmental Engineers and Scientists (AAEES) and the Association of Environmental Engineering and Science Professors (AEESP). SCENIC's focus on the environment sets the stage for place-based engineering with students in rural Colorado, a unique context in which schools often have access to the outdoors and students are likely to be closely connected to nature (Shamah & MacTavish, 2009). The environmental focus may also help broaden participation in STEM (Bielefeldt & Rulifson, 2018). For example, in contrast to engineering overall that awarded 22.5% of bachelor's degrees to females in 2019, the percentage was 52.1% in environmental engineering (ASEE, 2020). This is promising given that a key motivation for SCENIC is to support college pathways in engineering and science for rural students.

Theoretical Framing and Relevant Prior Work

SCENIC is informed by existing sociocultural theories on identity development and learning and their application to engineering, as well as empirical literature on how learning environments foster STEM learning and identity development. Within contemporary research on learning and human development informed by sociocultural and social practice theory, it is widely recognized that learning and becoming are inextricably intertwined (e.g. Holland et al., 1998, Penuel et al., 2016, Polman, 2012). In other words, what and how people learn is deeply related to their identities and identifications—who they are now, and who they and others see themselves becoming in the future. The theoretical framework of rural cultural wealth can help us view identity development and learning through the unique lens of rural learning environments. Rural environments are more than simply "not urban" and

> acknowledging the unique funds of knowledge and ways of being in diverse rural places (Sherfinski et al., 2020) is essential toward improving the educational outcomes of rural students and informing how the resourcefulness, ingenuity, familism and unity found within rural communities can be harnessed to improve education writ large (Crumb et al., 2022, p. 126).

Contrary to deficit-based perspectives, this framework allows us to view rural communities as rich environments for learning as we investigate place-based engineering with rural high school students.

The rural context is well supported in educational research as an optimal site for place-based pedagogy (Reagan et al., 2019); an approach to education that is both "a method and

practice of grounding learning in a student's sense of place or the lived experiences shaped by people, cultures, and histories" (Azano and Stewart, 2015, p. 2). The limited amount of research related to engineering and students in rural places has explored college-choice processes (Worsham et al., 2016), motivation (Beckwith & Hirshfield, 2021), and identity (Nixon et al., 2021). The fact that rural high school students in SCENIC pose locally relevant inquiry questions that are meaningful to themselves, and their rural communities, not only adds to the field, but it also helps drive student learning in several ways (NASEM, 2018; NRC, 2000). This place-based focus increases engagement (Polman & Hope, 2014; Tierney et al., 2020), and the application to real-world issues involving community members and local sites creates the need and rich contexts with contextual scaffolds for problem solving (Bouillon, 2001). In Hynes et al.'s (2017) systematic review of the literature on engineering education, an important theme of research beyond learning concepts and practices was developing students' perceptions, attitudes, beliefs, and motivations; SCENIC provides a promising opportunity to learn more about how students develop engineering mindsets toward solving rurally relevant environmental issues.

All too often, a purely technocratic framing of problems is prominent in science and engineering education (Gunckel & Tolbert, 2018). One important step in getting beyond the technocratic is including culture in studies of learning and becoming in STEM (NASEM, 2018). Research has shown that a powerful means of including culture and making learning both more meaningful and effective is connecting schoolwork to local communities (NRC, 2000). We draw on Crumb et al.'s (2022) framework of "rural cultural wealth" to make sense of the rural cultural context; this framework builds upon Yosso's (2005) ecologically situated, asset-based concept of "community cultural wealth." *Rural* cultural wealth consists of the following elements: (a) rural resourcefulness, (b) rural ingenuity, (c) rural familism and (d) rural community unity (Crumb et al., 2022, pp. 129-131). Resourcefulness refers to capacities of rural students to overcome adversities. Ingenuity refers to individual and collective inventiveness adapted to the community ecology. Familism refers to the asset of familial lineages within geographic proximity who collectively care for one another. And community unity refers to composite assets in rural populations that foster civic engagement. Rural communities tend to have a "strong communal identity"; these identities can represent a diverse set of cultures and experiences, and similarities such as "small, close-knit places with intergenerational connections to land with a strong sense of pride, community history and tradition" (Crumb et al., 2022, p. 126).

Place-based education is particularly congruent with environmental issues and has been found to be impactful for students living and learning in rural communities (Shamah & MacTavish, 2009; Smith, 2017; Sobel 2004), but has not been widely applied in engineering (Eschenbach et al., 2017). Accordingly, we will examine aspects of the outreach program's educational infrastructure that enable place-based science and engineering inquiry, aspects of place that inform rural students' selection of environmental monitoring topics, and how conducting these locally relevant projects contribute to rural students' engineering and science identity development. Furthermore, the intent and design of SCENIC is well positioned to respond to Crumb at al.'s (2022) call for researchers to "design place-based, contextual research studies using the constructs of rural cultural wealth to advance the understanding of diverse rural communities" (p. 133).

Project and Research Context

The SCENIC project began in 2013 as an outreach and engagement effort tied to an NSF-funded engineering grant, at one high school on the Western Slope of Colorado. As part of the larger

NSF effort, a lab at the university was building low-cost air quality sensing tools. Air quality sensors were installed at several locations in the community through a local environmental community organization, including the school itself. University students and faculty working on the project visited the school, and the teacher at the school became intrigued with involving his students in air quality sensing projects. The high school teacher and a graduate student collaborated on developing some lessons, and eventually a published curriculum unit, supported by university students and additional sensors ("Pods"). The effort spread to nearby schools in the same county over the following two years, and as shown in Figure 1, has since spread to 12 schools (mostly high schools and two middle schools). In the meantime, the project expanded from supporting just air quality inquiry, to supporting soil quality inquiry as well, with other low-cost sensor kits.

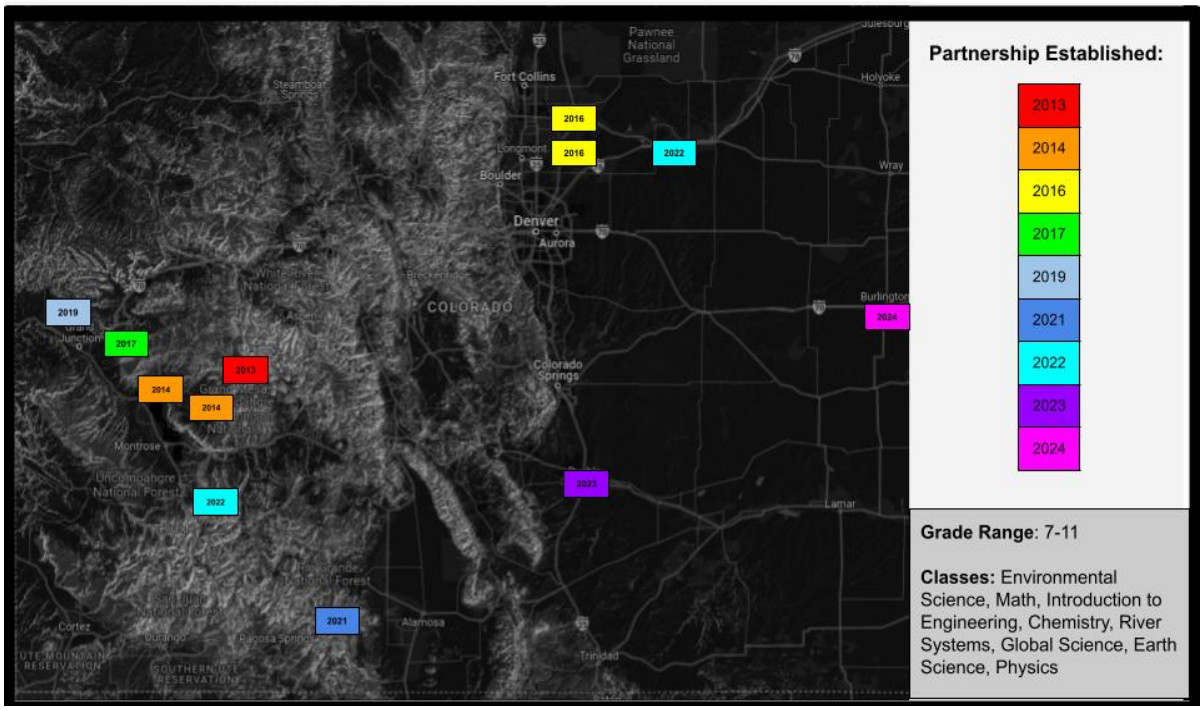

Figure 1. SCENIC Colorado school partnerships

To support and research place-based engineering in rural schools, SCENIC has many parts of its outreach program (Table 1; see also Knight et al., 2019). During the fall semester, the university undergraduate or graduate students involved in this project enroll in a course to receive specific training on how to mentor rural high school students, facilitate the use of the air and soil monitoring equipment (Pods), and implement inquiry-based curriculum. During the spring semester, these mentors travel to their partner school to bring the Pods and teach high school students how to use them to design and conduct soil and air inquiry projects that are relevant to their rural communities. The university mentors also interact with high school students and teachers remotely, supported by an on-line curriculum. As a part of our commitment to place-based pedagogy and the theoretical framework of rural cultural wealth, SCENIC also pairs students with local community members as sources to unpack the role of engineering in their communities. High school students engage local community members by monitoring environmental conditions in schools, businesses, agricultural settings, homes, and government

sites. Community members assist with access to experimental sites, materials, and project promotion. The soil and air quality inquiry projects culminate in a poster symposium where students showcase their projects to the local community.

Table 1. SCENIC infrastructure for place-based engineering in rural schools

Tools	• Integration into science courses available at the schools
	  o Rural schools do not need to have an engineering course
	• Soil and air quality monitoring equipment
	  o "Pods" provided by the university which could be too expensive for schools
	• Online curriculum, support and mentorship
	  o Remote learning using free curriculum

Partnerships	• Local partners (i.e., community members, businesses, ranches, etc.) • University partners (i.e., instructors, researchers, and other universities) • College undergraduate and graduate engineering student mentors • Rural high school students and teachers • Local science and engineering symposium organizers and participants

Methods

This work in progress is being carried out under a National Science Foundation Research in the Formation of Engineers beginning with the 2023-24 academic year, and continuing through 2025-26. We are using educational "design-based research" (DBR) methods (Bell, 2004; Design-Based Research Collective, 2003; Sandoval, 2014) with mixed-methods design to understand how, when, and why our innovation works in practice. DBR is an appropriate methodology to implement and understand human development in a sociocultural context, which will be particularly useful as this study is focused on understanding how place-based engineering impacts high school student learning in the rural context. Mixed methods are being implemented to investigate high school student participation and development, and how it is supported by the program's infrastructure (Table 1). Data sources to be collected during the project include interviews and surveys to collect data from rural high school students and their classroom teachers about student engagement, artifacts such as the symposium posters that the high school students create, and observations and fieldnotes from mentor school site visits and symposia. These methods will both inform the refinement of the materials and the approach for supporting high school student inquiry and advance our fundamental understanding of the underlying processes and mechanisms that support engineering identity formation for students in rural places. Analysis will explore how SCENIC Colorado supports experiences for rural high school students that are place-based, culturally responsive (Ladson-Billings, 1995), and sustaining (Paris & Alim, 2017), while catalyzing positive trajectories in STEM that integrate science and engineering.

Expected Implications

The project will advance knowledge regarding place-based engineering through the adaptation of cutting-edge university research tools for environmental monitoring for rural high schools in

Colorado. We hope to have an impact on enriching rural high school students' developmental and learning outcomes, particularly in ways that contribute to students' forming an identity as the kind of person who is interested in and engages with science and engineering. The design-based research and evaluation will contribute insights into what programmatic features or infrastructure support place-based engineering learning and development, and how.

This research project will help us understand how SCENIC's university-supported curriculum and mentoring impacts rural students, school districts, and local communities. We expect participating students to gain new knowledge, potentially form new identities, and benefit from increased connections to mentors who have traveled along pathways into STEM at the university level themselves. This has the potential for an especially important relationship between first generation high school students and university mentors. Students attending the rural high schools who participate in the projects are expected to benefit in terms of increased knowledge of STEM and more specifically engineering, increased science and/or engineering identity, and understanding pathways to engineering in college and downstream careers.

Research findings will contribute to the scholarship on science and engineering in rural schools. The design research and evaluation will contribute insights into what programmatic features of university student mentored research experiences support experiences for rural K-12 students that are culturally responsive and sustaining as well as support positive trajectories in science and engineering. The project will produce and disseminate tools including a roadmap for other stakeholders to implement for impacting engineering formation, while promoting rural spaces as rich places to do this work. Crumb and colleagues (2022) challenged researchers to "design place-based, contextual research studies using the constructs of rural cultural wealth to advance the understanding of diverse rural communities" (p. 9), and that is exactly what this research aims to do.

Acknowledgement

This material is based upon work supported by the National Science Foundation under Award No. 2318489, and by the University of Colorado Boulder Office of Outreach and Engagement. We wish to thank the rural high school students, their teachers and communities who contributed to this work. We also wish to thank the CU researchers who helped inform and sustain this work, including Mike Hannigan, Leighanna Hinojosa, Joe Kennedy, Kristen Okorn, Helene Pliszka, and Trang Tran.

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