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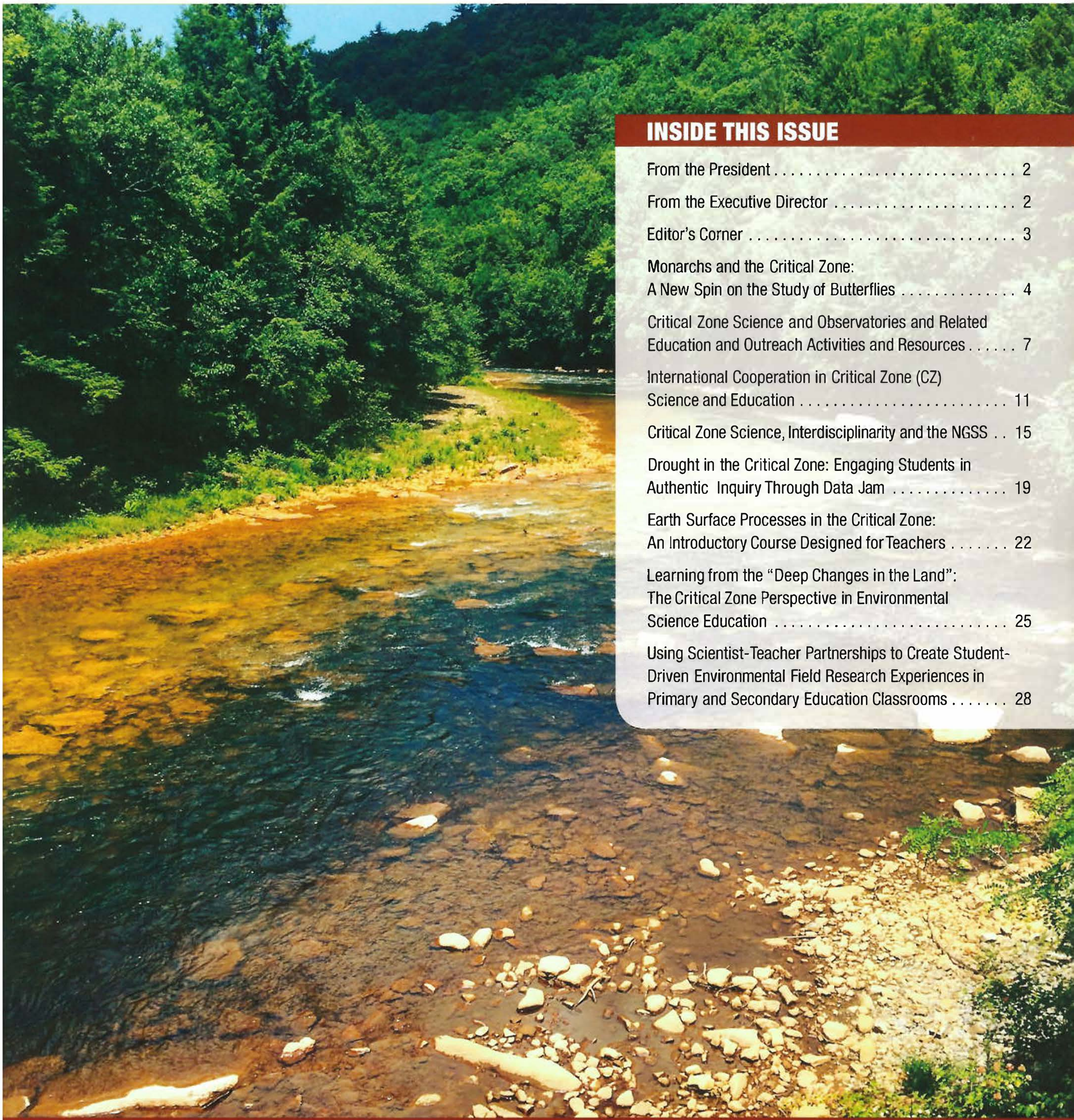

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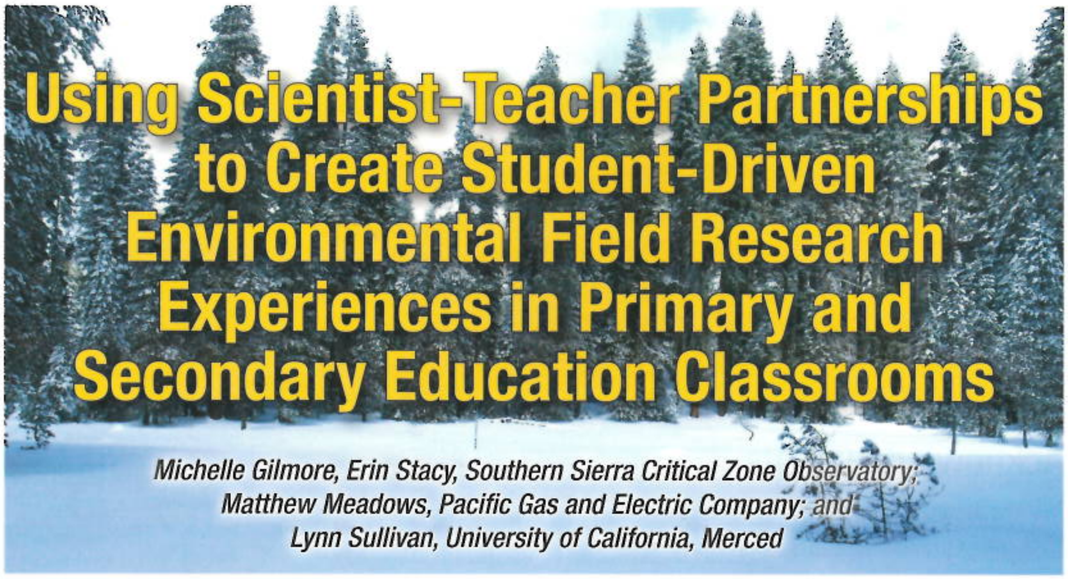

Using Scientist-Teacher Partnerships to Create Student-Driven Environmental Field Research Experiences in Primary and Secondary Education Classrooms

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Abstract

Teachers can partner with environmental professionals to create real-world research experiences for students answering field-based scientific questions. A partnership between staff from the Southern Sierra Critical Zone Observatory (SSCZO) and the Center for Advanced Research and Technology has resulted in six years of inquiry-based mentored research projects in the Sierra Nevada. While project background and mentoring are provided by professional scientists, our partnership empowers students to gain experience in the process of professional research through research question and hypothesis formulation, data collection and analysis, and communication of findings. This hands-on approach combining scientific research with learning supports the goals of the Next Generation Science Standards (NGSS). This article shares SSCZO's approach to student-driven environmental research projects and advice for teachers to start their own scientist-teacher partnership.

Overview of Project Partnership

Professional mentors can be a valuable resource for incorporating NGSS through the development of inquiry-based learning opportunities for students. Since 2011, SSCZO has partnered with a secondary school in Clovis, California, to mentor and empower students as they develop and implement environmental research projects. Students formulate research questions and hypotheses that fit within the scope of SSCZO research and test their hypotheses by directing their own field experiments. After collecting and analyzing data, students communicate their findings through research papers and conference-style presentations. Throughout the mentorship, students are kept accountable for their work as in a professional setting and exposed to potential career options in environmental science.

Mentored research projects align with the goals and approaches of NGSS (NGSS, 2013). Students' active participation in the scientific process can directly address the science and engineering practices of NGSS. Projects require students to apply multiple crosscutting concepts, including scale, proportion, and quantity; cause and effect; and patterns. Teachers can cover disciplinary core ideas in-depth with this project-based structure and use the project to assess performance expectations.

Our scientist-teacher partnership is based at the Center for Advanced Research and Technology (CART) [http://www.cart.org], a half-day 11th and 12th grade school with semester-based block scheduling that serves Fresno and Clovis Unified School Districts. SSCZO mentors one of several student research teams each spring in CART's Environmental Science and Field Research Career and Technical Education Program. Mentors meet with CART teachers prior to the project semester and submit research project proposals. Students review project descriptions, prepare a resume and cover letter, and interview in groups for their top project choices. Students' project interests and mentors' ratings of interviewees are used by the class' teachers to form project groups. Our approach with CART student research teams is detailed below, along with advice on creating your own scientist-teacher partnership.

Student Research Project Development

At CART, a group of six to nine students collaborate with one or two SSCZO staff mentors to develop a research project. Mentors meet with the student team to provide background information related to a general project topic. While the SSCZO conducts multi-disciplinary science, we typically develop projects focused on the water cycle of the Sierra Nevada. Based on this background, students work with mentors to identify potential questions to test, relationships to explore, or phenomena to quantify. The student team formulates their scientific question either through class brainstorming or out of a selection of predesigned questions. Hypotheses are developed from the overarching question based on student understanding of the subject.

Most students initially propose large-scale questions such as, "How much snow is needed to provide water for the farms in California?" It is important for teachers and mentors to channel creativity toward a project that students can handle based on time commitment, grade level, and project logistics. To help develop projects that students can complete, we start from a broad disciplinary core idea, such as cycling of water through an ecosystem, and funnel the topic toward a narrowly scoped project with real-world application (Figure 1). Chosen questions are often relevant to ongoing research at SSCZO and the management of Sierra Nevada watersheds and forests (e.g., Bales et al., 2011; Blankinship, Meadows, Lucas, and Hart, 2014).

Some examples of previous student project questions are:

- How much water is contained in a one-hectare area of snow?
- What are the effects of canopy closure on snow depth, snow water content, and snow density?
- How does vegetation density affect soil moisture in a forest?

Together, students and mentors develop an experimental design to test their hypothesis. Data collection for each hypothesis varies in spatial coverage and design (Figure 2). Protocols are developed based on established environmental field methods (e.g., Lemmon, 1956; Savage, 2003; Osterhuber, 2014).

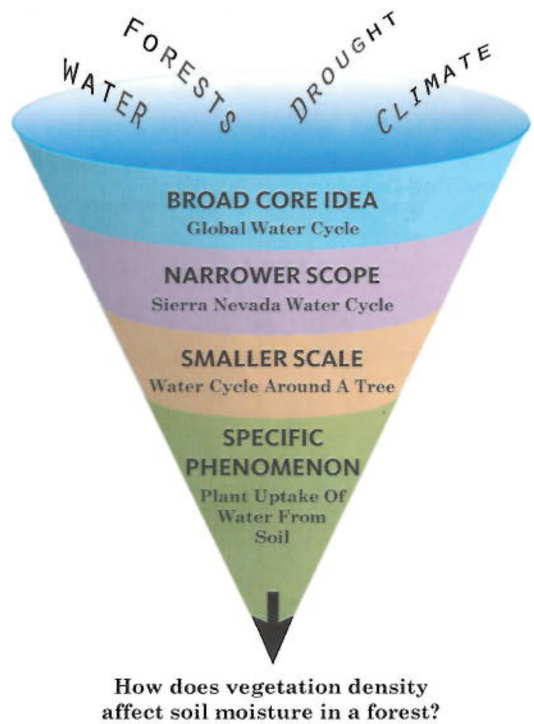


Figure 1. A funneling approach moves student research teams from broad environmental science topics to narrow final research questions as they brainstorm for their project.

Data Collection and Analysis

CART projects typically involve one day of data collection; some projects require multiple field days, such as topics exploring temporal changes or involving multiple field sites. In the field, mentors and teachers monitor student safety and ensure effective measurement technique, sampling coverage, and time management. Students collect and record data themselves, often collecting the same data as professionals, such as GPS information, snow water content, and soil moisture.

Before collecting data, mentors train students to use field instruments, such as snow water content samplers, soil moisture meters, and spherical canopy densiometers. Mentors can provide

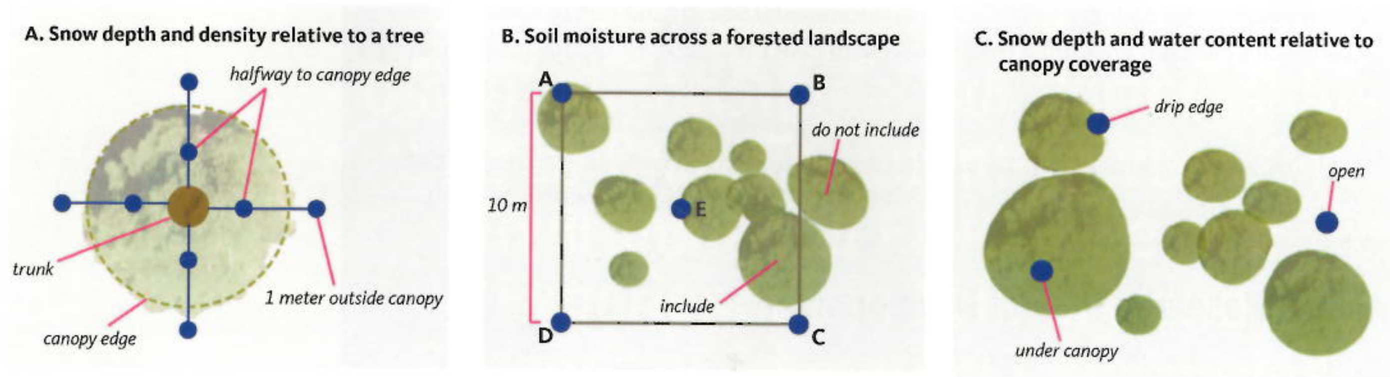
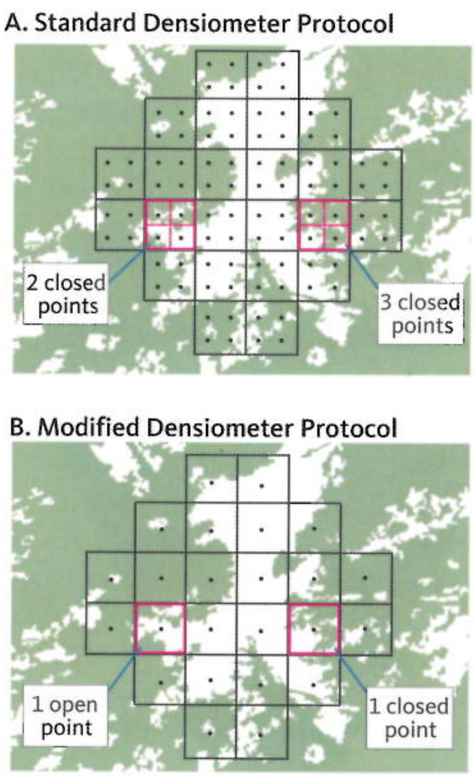


Figure 2. Examples of protocols for students' research projects. Blue circles represent measurement sites. A. Students recorded snowpack measurements under and outside tree canopies. Ground slope and tree species information were also recorded. B. Students conducted soil moisture and vegetation surveys in several square plots categorized as "dense", "medium" or "sparse". Teams measure soil moisture at the corners and center of the plot, tally tree and shrub species, and measure trunk circumference for all trees and large shrubs. C. Students recorded canopy closure and snowpack measurements at several sites in a forested area, classified as open sky, canopy drip-edge, or under-canopy zones.



a professional data recording format or work with students to design a data recording format tailored for their project. Depending on time available, method complexity, and student skill level, it may be helpful to simplify some measurement protocols. For instance, one CART team used a simplified approach to measure tree canopy closure percentage with a spherical canopy densiometer. Spherical densiometers contain 24 engraved squares on a mirror, which users usually divided into quadrants. The number of quadrants, or points, covered by canopy, are counted out of 96 total points (Lemmon, 1956) (Figure 3a). This protocol was modified, counting each square on the densiometer as a single point and determining coverage out of 24 (Figure 3b). The procedure modification reduced precision of canopy closure measurements but allowed students to save time and sample more sites.

After data collection, students transfer field data into spreadsheets and mentors advise the team on data analysis techniques and visualizations. Depending on research topic, students may incorporate additional pre-existing data into their project, either from previous student projects or other data libraries. Teachers and mentors support students as they learn and practice technological skills to analyze their data, such as graphing in a spreadsheet, manipulating data through computer coding, or importing GPS data into mapping software. The team uses online spreadsheets, slideshows, and other documents during and between research team meetings to collaboratively edit, answer questions, and offer feedback on project progress.

During data analysis, mentors facilitate discussion with students to help them understand their findings and draw conclusions from their work. For instance, one team discussed how interception, albedo, and heat transfer contribute to observed patterns between canopy closure and snow distribution (Figure 4). Teachers can deepen student understanding of new concepts and processes and relate project activities to other ongoing classwork.

Figure 3. A. The standard spherical densiometer protocol requires mentally dividing each of the 24 squares engraved on the densiometer into four quadrants. B. A modified the protocol allows students count each engraved square as a single point.

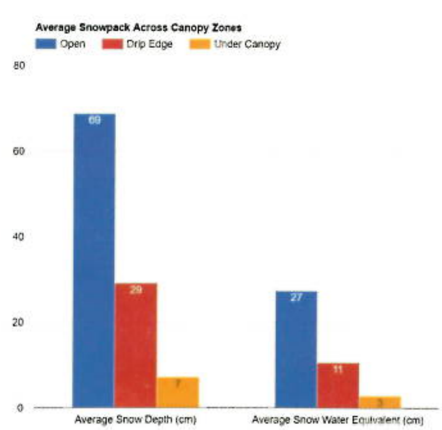


Figure 4. A graph created by CART students illustrating differences in average measured snow depth and snow water content in open, canopy drip edge, and under canopy areas.

Communicating Research with Peers and Others

Explaining project concepts, workflow, and findings through papers and presentations allows students to show understanding of their work and experience the research project to completion. CART students write a research paper and present their project to their peers, parents, and public attendees at a research symposium. Mentors and teachers advise and collaborate with each team to generate their presentations. Students may also design figures for their presentation to explain their research (Figure 5). Student teams are encouraged to seek feedback from peers and mentors through practice presentations with other groups and mentors in a mock symposium.

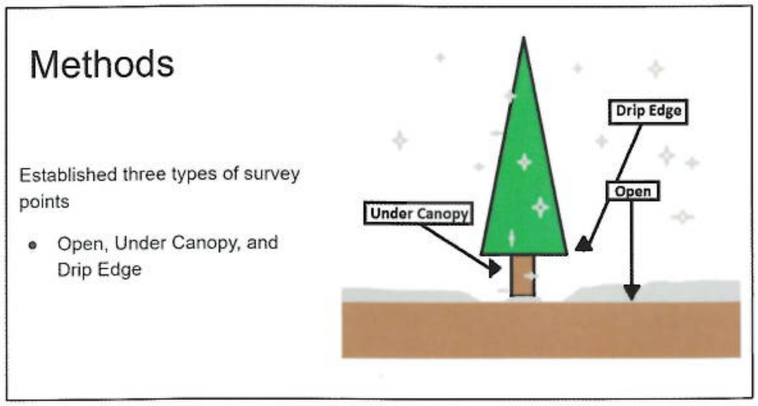


Figure 5. A student-made figure used in a CART symposium explaining three canopy zones and sample site selection.

Teams also have the opportunity to present their findings to the broader science community and public through science fairs, scientific conferences with student research sessions, and presentations to stakeholders or colleagues of a mentor. Journals focused on student research are another potential outlet for sharing students' work.

Initiating a Scientist-Teacher Partnership

You might be saying, "I don't know any researchers or environmental professionals!" Finding a scientist mentor might be easier than you think. CART has gradually built partnerships with mentors from SSCZO, USDA Forest Service, Pacific Gas & Electric Company, and other diverse groups spanning a range of STEM disciplines. Consider searching at local colleges or universities, research programs, non-governmental organizations, State and Federal agencies, as well as private companies. You may narrow your mentor search based on the NGSS disciplinary core ideas that apply to your grades and subjects. All you need is one mentor to get things started; they can help build and diversify your mentor base over time.

SSCZO is one of ten observatories around the United States in the National Science Foundation's Critical Zone Observatory Program [http://www.criticalzone.org]. Each observatory researches multidisciplinary science topics upon which your class could build. There may be an observatory or other research program nearby that could mentor your class.

Additional considerations for a scientist-teacher partnership include time commitment of the work, both during and between mentor meetings; fit of project within a class' curriculum; and size of your research team or classroom. CART projects usually have less than 10 students on a research team, with multiple mentored research projects happening in class at once. Larger classroom projects may require different approaches to keep student teams engaged and productive. It is important to keep students motivated and empowered throughout the research project.

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