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Board 434: Work in Progress: On the Use of Low-Cost Environmental Monitors in rural K-12 Outreach to Enhance Engineering Identity Development

Dr. Daniel Knight, University of Colorado Boulder

Daniel W. Knight is an Associate Research Professor at Design Center (DC) Colorado in the University of Colorado Boulder Department of Mechanical Engineering at the College of Engineering and Applied Science.

Dr. Angela R Bielefeldt P.E., University of Colorado Boulder

Angela Bielefeldt is a professor at the University of Colorado Boulder in the Department of Civil, Environmental, and Architectural Engineering (CEAE) and Director for the Engineering Plus program. She has served as the Associate Chair for Undergraduate

Dr. Joseph Polman Polman

Joe Polman is a Professor of Learning Sciences and Science Education, as well as Associate Dean for Research, in the School of Education at University of Colorado Boulder. He designs and studies project-based learning environments for youth in schools and

Prof. Michael Hannigan

Michael P. Hannigan is an Associate Professor in the University of Colorado's Department of Mechanical Engineering. He holds a B.S. in Civil Engineering from Southern Methodist University and a M.S. and Ph.D. in Environmental Engineering Science from Calt

Work in Progress: On the Use of Low Cost Environmental Monitors in Rural K-12 Outreach to Enhance Engineering Identity Development

Overview

This paper describes a Design and Development project funded under the Research in the Formation of Engineers (RFE) program by the National Science Foundation. The project is investigating and refining an educational infrastructure for supporting engineering and science learning and identity formation in an outreach program in rural Colorado high schools. Design-based research will both inform the refinement of the materials and approach for supporting high school student inquiry, and advance our fundamental understanding of the underlying processes and mechanisms that support engineering identity formation.

Background

In the United States, rural settings are an important and frequently under-resourced and under-researched [1] cultural context for education, despite the fact that approximately half of school districts, a third of schools, and a fifth of students in the United States are located in rural areas [2; 3]. Rural students are underrepresented among college attendees and STEM majors [4; 5]. Programs aimed at professional engineering formation among rural students may help close this gap. To design effective programs, a greater understanding of the formal and informal processes and value systems by which K-12 students explore the engineering pathway is needed—including development of identity as an engineer and intersection with other identities; development of outlooks, perspectives, ways of thinking, knowing, and doing; and acculturation to the field and potential careers.

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 [6]. Place-based education may be particularly impactful in rural settings [7; 8]. This study therefore will refine a unique rural program, the Colorado Science and Engineering Inquiry Collaborative (SCENIC Colorado), based on design-based engineering education research.

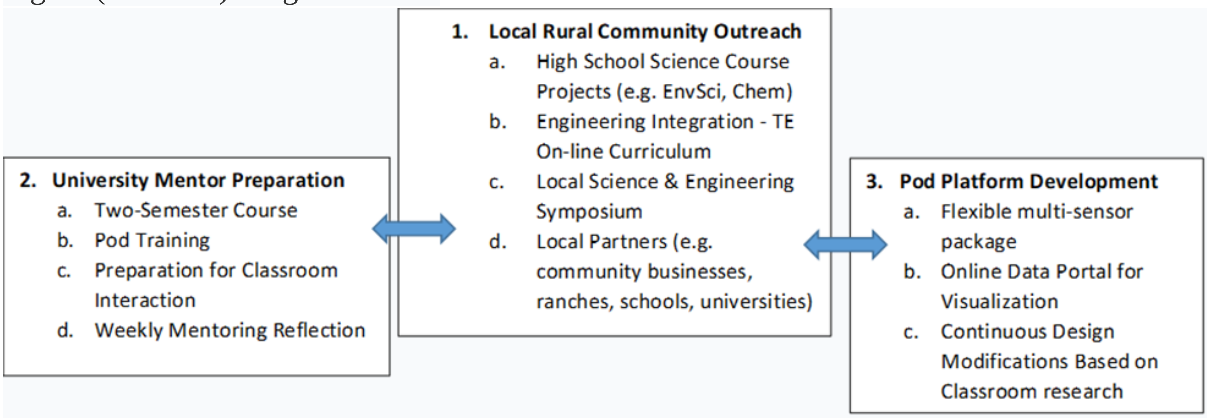
Program Overview

The three interrelated components of the SCENIC Program are shown in Figure 1:

1. Provide rural community outreach,
2. Prepare and deploy university mentors to support rural schools,
3. Refine and adapt Pod environmental monitoring platforms to support inquiry projects.

Components 1-3 represent supporting components of the SCENIC program. The continuing development of these components will enable and drive the education research. Component 1, in the center of Figure 1, depicts the local rural community outreach focused on an inquiry-based curriculum about student-driven air and soil quality projects for high school science classes (1a in Figure 1). As these rural schools mostly lack engineering content, linking environmental engineering into science courses may serve to attract students to engineering [9].

Fig. 1: (SCENIC) Program Model



Initial versions of the air quality and soil quality curricula known as (AQIQ) and (SQIQ) have been implemented and we are refining them (1b in Figure 1). (AQIQ) has been published in the TeachEngineering Digital Library (an on-line, open access digital library) [10], and follows a five-module structure focused on an introduction to the air and soil quality content, an introduction to the environmental monitoring technology known as a Pod, and data analysis and visualization lessons. (SQIQ) curriculum follows a similar five-module structure and will be made available on-line in preparation for publication on TeachEngineering.

High school students are guided in the execution of a project by university student mentors and high school teachers. During the fall semester, university students are prepared to mentor K-12 projects. Projects are conducted during the spring semester and supported by university laboratories in the iterative design and integration of laboratory environmental monitoring Pods. High school students engage local community members by monitoring environmental conditions in local schools, businesses, agricultural settings, homes, and government sites. Community members assist with access to experimental sites, materials, and project promotion. Community members are invited to the symposium. Two mentors will travel monthly to each school in the spring semester and support projects remotely via an on-line curriculum (See Component 2). The SCENIC projects culminate in a local symposium where students showcase their projects to the local community (1c in Figure 1). Symposiums incorporate judging of student poster presentations and a keynote address from a university partner.

Component 2 is in the left box of Figure 1 and represents the preparation of the university mentors for guiding high school student projects. Undergraduate and graduate students will be educated as mentors through a two-semester mechanical engineering course that has a community engagement component (2a in Figure 1). A course TA, student travel and symposiums are supported by the mechanical engineering department as part of the course. Mentors begin the fall semester working through the same inquiry-based curriculum that they will facilitate with high schools in the spring. The preparation includes practice with the curriculum and Pods including troubleshooting skills necessary for non-commercial laboratory equipment (2b and 2c in Figure 1).

During the spring semester, high school projects begin with a week-long launch in high school classrooms. Mentors receive logistical support to complete their monthly trips. Mentors also engage in weekly teaching reflections in a variety of forms [11] and receive instructor and peer feedback (2d in Figure 1).

Component 3 is focused on the adaptation and integration of the Pod platforms and is the right box in Figure 1. To support the implementation of high school student environmental monitoring projects, Pods include a flexible multi-sensor package for gathering a variety of environmental data (3a in Figure 1). Sensors are connected to an on-line portal for data visualization that provides graphs of the sensor output (3b in Figure 1). Pod design is conducted annually with university student design teams working on prototypes using input from partner labs and education research practices. The Pods have undergone refinement for increased durability over the years. Both the Pods and the data visualization portal have been refined for usability and supporting learning over the years as well; the proposed project will continue this refinement through design-based research techniques.

For the first year of the NSF award, (SCENIC) is serving 12 rural schools in Colorado. This program is partnered with eight school districts, 14 middle and high schools, and 601 students. 25 university mentors, and 3 faculty will work with the partner middle and high school students to develop and present air and soil quality projects. In addition, an education research team composed of 3 faculty members and 2 education graduate students will conduct research on the impact of the program on participants.

Project Case Studies

K-12 projects are under development for the first year of the award. However, (SCENIC) student mentors complete a project during the fall semester similar to the one they will mentor in their partner middle and high schools in the spring and these projects provide some useful case studies to illustrate the nature of the projects associated with the program.

Case Study #1

Projects often follow student hobbies. An example mentor air quality project investigated the impact of gun smoke from different types of firearms on the person shooting the gun. A university student went to a shooting range with five of their personal firearms and tested emissions using a Pod. The student hypothesized that firearms that tend to vent gases rearward will expose the shooter to more pollutants. Additionally, the usage of a sound suppressor will significantly increase the effects of backpressure venting.

The student followed this procedure:

1. Pod is powered on to read baseline conditions for 20 minutes.
2. Note and document weather.
3. 5 shots are fired with pod near the shooter’s face.

4. Note the time, firearm type, and number of shots.
5. Wait 5 minutes for the next trial.
6. Repeat with all trials.

The university student conclusions supported the hypothesis as firearms that vented gases rearward showed a significant increase in pollutant readings. Tests with an attached suppressor saw drastically increased pollutant readings in all pollutant types. It should be noted that this experiment was conducted with auto-loading firearms, which do not seal as well as manually operated firearms. Throughout the process the university student placed a heavy emphasis on safety and responsibility in the use of firearms.

Case Study #2

Another topic for student projects investigates the impact of various products on air quality in the home. An example air quality project in this area investigated the impact of different types of candles on air quality in the bathroom. A university student tested three types of candles and tested emission using a Pod. The student hypothesized that candles that contained more natural ingredients would emit less pollutants. The student followed this procedure.

1. Set unlit candle below Y-pod.
2. Turn on Y-Pod, calibrate for 30 minutes (door closed).
3. Light candle, let burn for 1 hour (door closed).
4. Blow out candle, leave for a few minutes (door closed).
5. Repeat Steps 1-4 (new candle).

The student found that the soy wax candle produced less pollutants than the beeswax candle. This went against her hypothesis as the beeswax candle had more natural ingredients. The coconut wax candle did not burn properly and was a source of error.

Case Study #3

A third topic common to student investigations is outdoor air quality. An example in this area is emissions from a construction site. A university student tested emissions from a construction site at different distances and hypothesized that those closer to the site would experience higher levels of particulates than those further away. The student followed this procedure.

1. Measure distance between construction site and testing site.
2. Set up testing station at measured distance, away from interference.
3. Turn on air quality monitor for 30 minutes.
4. Report notes during testing about weather, construction equipment used, and other variables that could influence date.
5. Turn off air quality monitor.

The student found higher amounts of particulates closer to the construction site and his hypothesis was supported.

Education Research Plan

The education research for the (SCENIC) program will be conducted by the school of education and is centered around a design based model that provides on-going iterative research results on the program implementation processes, and their impact on participants. Mixed methods including surveys, interviews, and observations will be implemented to investigate high school student participation and engineering identity development, and how it is supported by the program's infrastructure—including curriculum, high school teachers, (SCENIC) mentors, and tools. The education research will also examine how rural communities and cultures influence processes and outcomes.

These are our research questions:

RQ1: How do aspects of the outreach program's educational infrastructure support rural high school students' participation in and identification with engineering and science?

RQ2: How does conducting locally relevant environmental monitoring contribute to rural students' engineering and science identity development?

In terms of specific research methods, we will use mixed-method design involving data from classroom observations, student produced artifacts, student and teacher interviews, and student surveys. To respond to RQ1 and to understand the conditions within the infrastructure that contribute to students learning how to participate in science and engineering practices, we will conduct interpretive case studies [12] of a stratified sample of students and groups from each high school involved in the study. These case studies will focus on the relations between the embodiments, the mediating processes, and the outcomes in the conjecture map. Data sources for these will include field notes and recordings from participant observation (in-person and virtual, as in [13]), interim and final artifacts created by students (e.g., assignments, posters), and end-of-program interviews with students.

Table 1 STEM Identity Survey Items (adapted from [14], p. 474)

Variable	**Items**
Identity	I see myself as a STEM person
Interest/attitude	Topics in STEM are exciting to me I am interested in learning more about STEM
Recognition	My teachers see me as a STEM person My friends/classmates see me as a STEM person My family sees me as a STEM person Others ask me for help in STEM
Performance-competence	I feel confident in my ability to learn STEM I can do well on tests and exams in STEM I understand concepts I have studied in STEM

Current Progress on the Award

At the time of writing, we have made progress on a number of aspects of the award. The university mentor course known as Project Based Learning in Rural Schools has its largest cohort in the history of the course (n = 25) and the mentors have been trained and completed their first two visits to their schools to teach the curriculum. Mentors have spent time in the university classroom reflecting on their visits and identifying successes and strategies for improvement for the next visit.

We have added two new partner schools in rural eastern Colorado and air and soil quality projects have been launched in twelve rural Colorado schools. We have also revised our soil quality monitoring Pod to make it easier for K-12 students to use and have placed the new Pods with the schools. The Education research team has three faculty members and a graduate student integrated and is engaged in initial qualitative data collection activities. The team looks forward to additional data collection and analysis throughout the spring and summer. Assessment practices are under way to investigate the long range sustainability of the program.

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Declarations

This project is being conducted in accordance with research reviewed by Institutional Review Boards for Human Subjects Research.

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