# WIP: Rural Water Education (RWE) Partnership for Place-Based STEM Learning in Out-of-School Programs


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***Abstract*— This innovative practice WIP paper describes a cross-disciplinary collaboration between middle school educators, educational researchers, and civil engineers and scientists to design a series of community-centered STEM learning activities focused on water quality and local water concerns in the southeastern United States. The RWE partnership promotes STEM literacy and workforce readiness for students in grades 6-8 through hands-on STEM learning, student-led research projects, and advocacy opportunities based on water treatment and wastewater-related research occurring in a rural community.**



***Keywords—inclusivity, middle school, sustainability, informal learning, expectancy-value theory***


## I. Introduction

Science and engineering directly impact our everyday lives, solving challenges in our communities and helping our neighbors with new technology and knowledge. Expectancy-value theory [1] suggests that revealing this profound influence through place-based STEM experiences may be key to engaging a broader range of students in the STEM workforce, including underrepresented groups. The place-based after-school learning experience at the center of this study was designed to highlight how STEM research aligns to the values and priorities of students in these communities. For example, research shows that rural, female, and Black students are more likely to have career values that focus on helping others or serving their local community [2]. To this end, the Rural Water Education (RWE) Partnership takes a place-based approach to bring together university, school, and community partners with the shared goal to promote STEM literacy and workforce readiness for students in grades 6-8. Through hands-on and engaging STEM learning, student-initiated research projects, and advocacy opportunities based on cutting-edge water and wastewater-related research already occurring in students' communities, the RWE aims to support and improve students' science learning and recognition of community connections to STEM.

The RWE approach, which we detail further below, focuses on community- and personal-relevance for students, connecting to broader movements toward more culturally sustaining, youth-centered, and place-based STEM education [3], [4], [5]. Place-based learning is meant to deeply intertwine students' STEM learning experiences with their sense of place and their cultural and personal connections to their community, to "provide context and reason for learning" [6] (p. 3). In this way, students build connections between the STEM content they learn in classroom settings and the implications of their learning to solve community-related issues in STEM, as well as innovations and applications in local industry. Drawing from frameworks embedded in culturally relevant pedagogies (CRP) [7], [8], place-based approaches to STEM teaching and learning also emphasize the importance of students' everyday experiences and the funds of knowledge of their community, thus aligning with the goal of CRP to teach "to and through [students'] personal and cultural strengths, their intellectual capabilities, and their prior accomplishments" [8] (p. 26). Focusing on the values held by many rural students, including serving their community, and highlighting the local relevance


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of STEM is believed to increase interest in the field for K-12 and university students.

To this end, centering community-related water concerns has been an essential feature of the RWE Partnership project. Our partner school is located in the Alabama Black Belt, a region affected by multiple water-related community challenges, including issues with public water treatment services, impacts of hydroclimatic events (such as floods, hurricanes, and drought), and detrimental effects of agricultural spill-off on local waterways. Community agencies within the region, along with local university-based scientists and engineers, have been working together to understand the effects of these water challenges and to create innovative solutions that will improve the quality of life and well-being for both community members and the local ecosystem [9]. The choice of water as the curricular focus was very intentional due to the scientific and engineering research already underway in the region provide the context for hyper-local and engaging science curriculum as well as student-initiated research projects.

Bringing in middle school students and their teachers as meaningful contributors and research partners in these ongoing efforts has afforded students the opportunity to deeply learn about water and its importance, to take ownership of their learning, and to feel empowered as community members whose voices matter not just for the future, but now [10], [11].

Moreover, learning about research in the community also supports teachers' efforts to engage in three-dimensional science teaching, wherein students learn not only the concepts of science, but also engage in the practices and cross-cutting concepts of the disciplines as part of their school science learning [12], [13]. Traditional approaches to science teaching tend to prioritize content acquisition through memorization, didactic methods of delivery, and confirmatory laboratory experiences for students. Teaching science in three-dimensional ways requires teachers to not only teach the content and ideas of science, but also engage students in the methods, practices, and habits of mind that are inherent to science and engineering—and these become important learning outcomes in their own right [14], [15], [16]. With this in mind, the RWE Project aims to support partner teachers to better engage students in STEM learning by centering students as doers, thinkers, and partners in the scientific research, and positioning both teachers and students as agentive in their learning.

By partnering middle school teachers and students with water science researchers in the Alabama Black Belt region, this work aims to act as a 'proof of concept' for the deep STEM learning possible through the development of multi-stakeholder, place-based community-centered STEM research endeavors that prioritize the values and interests, cultural and communal knowledge repertoires, and needs of students and their communities.

## II. Innovations

The RWE partners are providing afterschool STEM activities designed for middle grade students in a rural, predominantly Black (98%), and low-income (93%) area. This work is in an afterschool setting with in-service teachers allowing them to experiment with new teaching methods in a low-stakes environment. The afterschool time also allows teachers to extend their relationships with the students and observe different aspects of students' academic talents in this informal environment. Additionally, water researchers from nearby universities and community organizations serve as support facilitators who co-develop the lessons and sometimes co-teach with the teachers and provide context for the hands-on activities.

Such interactions between students, teachers, and university scientists and engineers from the community can humanize researchers—allowing them to share their passion and expertise, and to show how their highly technical work can directly impact students' communities [17]. Moreover, connections with local STEM professionals allows students—and teachers as well—to understand that science and engineering work is done by 'real people' who live in their communities and have diverse backgrounds and lived experiences [18].

Community-related water concerns are an essential feature across the team-developed STEM activities in effort to embed cultural, community, and personal relevance to students' learning experiences. Water in this regional context is of critical concern due to inadequate wastewater solutions, impacts of hydroclimatic events, and impacts of agricultural practices. Hands-on lessons have been developed by the RWE team of classroom teachers, educational researchers, and water experts to highlight the relevance of water-related science to local water concerns. Specifically, these activities were designed to support students' understanding of water research as connected to their local community needs, on ecological and human health, and how scientific research can inform policy and advocacy initiatives.

As students engaged in these activities and interacted with scientist facilitators, it was also expected that students' awareness of career opportunities—in local rural contexts and beyond—would increase, raising their STEM-related self-efficacy and interests. We also hypothesized that this collaboration would promote the STEM skills and career awareness of participant teachers and provide opportunities for STEM researchers to build their skills and capacity for educational outreach and public communication of science.

Water-related lessons occurred one day each week during the program (with other days focusing on other STEM topics). In Spring 2024, we provided nine lessons on wastewater treatment processes and how soil and environmental conditions make traditional wastewater systems (such as septic tanks) less effective in the local region of the Alabama Black Belt area. Two soil lessons (Dig Into Soils, Parts 2 & 3) were adapted activities from the Soil Science Society of America's K-12 Soil Science Teacher Resources website (https://www.soils4teachers.org/lessons-and-activities). The other soils activities (Dig Into Soils Part 1 and CLORPT Explorers 1 & 2) developed specifically for the RWE project. See Table 1.

Other weeks of the program focused on wastewater, which is often described as consisting of five stages [19]:

- Coagulation, where additives neutralize the negative charge of dissolved materials so they can bind together
- Flocculation, which is a process of agitating the water to encourage the dissolved materials to clump together in "flocs"
- Sedimentation, where the flocs settle at the bottom of the container
- Filtration, where filters with various pore sizes and properties help remove additional dissolved particles and contaminants
- Disinfection, the final stage where remaining contaminants, especially bacteria and viruses, are killed to ensure the water is safe to be released back to the environment.

Students completed a sedimentation experiment, comparing the settling time of muddy water with and without a coagulant (alum). Another lab used an adapted version of a common water filtration exploration (https://tryengineering.org/teacher/lesson-plans/filtration-investigation/), considering the pore size of the various filter media using microscopes.

Finally, one of the most popular labs focused on disinfection. Students swabbed various surfaces (their hands, phones, lab tables) before and after treatment with their choice of a consumer disinfectant product (UV-based products, cleaning wipes, soap and water). Using agar plates for the medium, they were able to observe evidence of bacterial contamination the following week. This lesson involved classic scientific tools and an experimental design that the students found very motivating.

TABLE I. CURRICULUM TOPICS

| Topic | Activities |
|---|---|
| ***Soil*** | |
| *Introduction to soil basics and maps* | "Dig Into Soils, Part 1" - Introduction to soil forming factors (climate, organisms, relief, parent material, time, or CLORPT). Spatial analysis of different soil types in Alabama and how they formed using soil, climate, and topographic maps of the state, highlighting the Alabama Black Belt. |
| *Soils physical and chemical properties (profiles and color)* | "Dig Into Soils, Part 2" - Students take core samples of local soil and identify the different soil profiles. Learn to describe the soil based on Munsell color charts. Adapted from "A Soil Profile" activity from www.soils4teachers.org (Soil Society of America). |
| *Soils physical and chemical properties continued (texture and infiltration)* | "Dig Into Soils, Part 3" - Soil properties of compaction and clay content determine the amount of time it takes for water to infiltrate the ground with an in-situ infiltration test. Adapted from "Rain and Soil" activity from www.soils4teachers.org. |
| *Soil Geography and Geospatial Technology, Part 1* | "CLORPT Explorers, Part 1" - UC Davis Soil Web paired with core samples of local area to determine how soil composition (clay vs. sand) affects soil properties. Microscopic analysis of core samples provided additional visual distinction between separate sites. |
| *Soil Geography and Geospatial Technology, Part 2* | "CLORPT Explorers, Part 2" - Students use UC Davis Soil Web to explore and hypothesize how CLORPT plays a part in soil formation in the major cities of Alabama. Explored suitability ratings of the soil for agriculture, construction, and water runoff. |
| ***Waste Water*** | |
| *Wastewater sedimentation, turbidity* | Introduction to wastewater sanitation procedures video. Using local soil cores, students conducted a flocculation alum experiment to see how the addition of chemicals causes different sediments to floc at different rates. |
| *Five types of waste water sanitation* | Disinfection experiment with varied sanitation methods including standard practices and consumer UV sanitation products for coliform growth on agar plates. |
| *Water quality testing* | Introduction of water quality topics of pH, turbidity, phosphates/nitrates, and coliform testing of water sources. Local water sources were provided for testing with low-cost water monitoring kits. In addition, students identified other water sources to test (water filters with red warning lights). |
| *Surface area and molecule size, sediment transport* | Students used calipers to measure and calculate surface area of "molecules" (marbles vs. tennis balls). The amount of each "molecule" that can fit into a container. The surface area of molecules determines how sediments transport different materials (lead 210). |

## III. METHODS

Our partner school is a Title I middle school (grade 6-8) that is 98% Black or African American. Our partner teacher is a Black woman with an Ed.D. and a background in biology. Our university research team included one Black woman and four white women as collaborators, three with backgrounds in education and two from the geosciences. Attendance by students varied with sports and other commitments, but we typically had 10-20 students participating each week.

We are in the first year of implementation with a federal grant supporting this work for 18 months. We offer water-related lessons one day each week during the program (other days focus on other STEM topics). Each week of the spring lessons, students were asked to complete an exit slip where they briefly summarized the lesson and checked all of the experiences or emotions from the lesson that day. This checklist included:

- Excited
- Frustrated
- Challenged in a good way
- Interested
- Bored
- Confused
- Like a team member
- Confident
- Engaged
- Creative
- Collaborative
- Like a scientist
- Like an engineer
- Connected to the real world

We asked students to complete the Role Identity Survey (RIS-STEM) at the start and end of the spring term.[16] We also conducted qualitative interviews at the end of the program year to explore the effects of these lessons on students' identity formation. Some of the interview questions included:

- *When you think about all of the Wastewater activities & project* - What did you like best about the wastewater activities? What did you feel like you were learning?
- How are the activities you've been doing each week in STEM club connected to your community and/or home?
- How do you feel when you're doing science and engineering activities in STEM club?

- What kinds of careers do you know about that are related to STEM or use ideas and skills related to STEM?

## IV. Results

Due to time constraints, exit slips were only used in six of the nine spring lessons. See Figure 1a & b. The lesson about water quality testing led to the highest ratings of students indicating the felt “like a scientist” and “connected to the real world.” An interesting finding was that students rarely indicated any lessons made them feel “like an engineer” despite the content being closely tied to civil engineering concepts. We may need to emphasize career connections more or this may be due to widespread misunderstandings of engineering and the work of engineers[21].

FIGURE 1A SOIL EXIT SLIPS

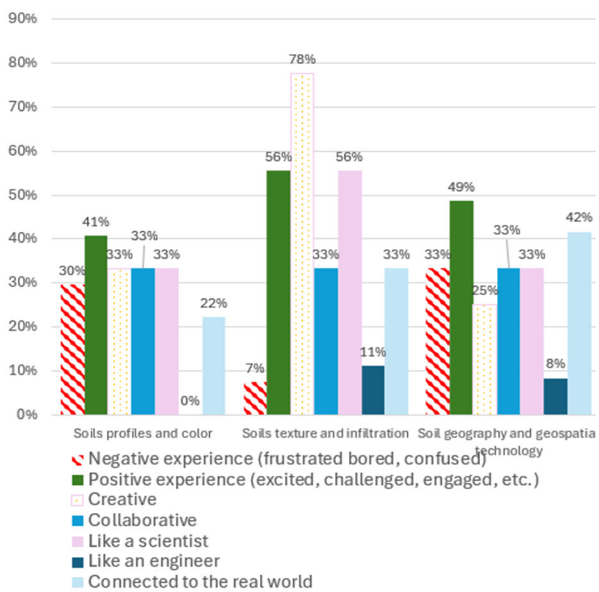
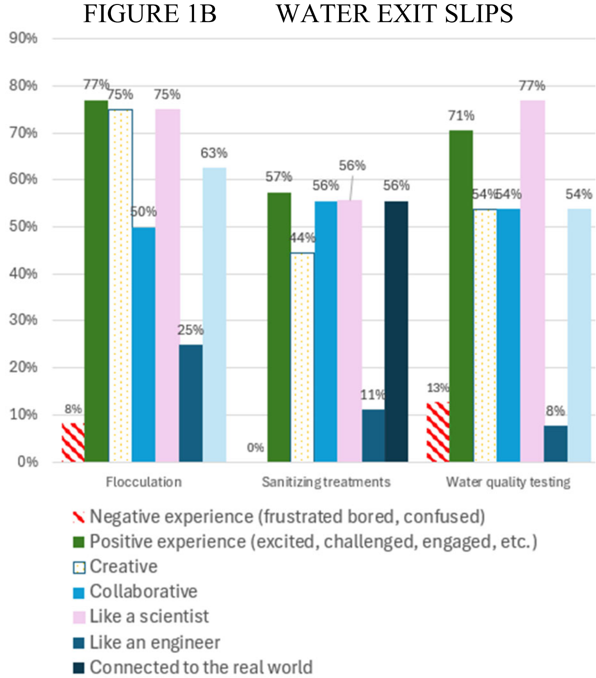



FIGURE 1B WATER EXIT SLIPS




We also found that the lesson on soil profiles and colors was not particularly engaging. This lesson introduced a lot of technical terms and could be modified to emphasize essential concepts and practices, which we think would increase engagement. This lesson included taking soil samples using a soil probe, which students enjoyed (as reported at the time) because it was outside, but the analysis of colors and layers inside could be improved. Additionally, more context could be provided to students about the importance of making observations prior to developing hypotheses and developing tests in science.

These results are consistent with the qualitative interviews, where students felt most like a scientist in the weeks when we did water quality testing and sanitation. In the sanitation lab, students were able to swab various surfaces (their hands, phones, lab tables) for an agar plate before and after treatment with their choice of a consumer disinfectant product (UV light, cleaning wipes, soap and water) to see if it affected bacterial contamination. This lesson involved classic scientific tools and an experimental design. In the water quality testing, students interpreted several tests to evaluate the quality of their water samples, which were taken from a nearby river and water fountains in the school. Students came up with the idea to compare water from a water fountain where the filter indicator was green vs. Another one in the building that had a red indicator. The ability for students to identify as “feeling like a scientist” through educational activities that involve methods and tools that are similar to a “lab” environment is a positive outcome, as this suggests students may consider science as a career path open to them. But it is also suggestive of the pervasiveness of societal stereotypes that scientists only work in labs.

### A. *Changes in STEM identity*

Nine students completed the pre-unit survey and 10 completed the post- survey. Only five were matched and the rest were from other regular attendees who happened to miss or one the other date. The table below shows an independent samples analysis (df =18) which comported with a Wilcoxon signed rank test for the paired data, which was more appropriate given the matched data, but based on only five respondents. In both cases, the gain in self-efficacy was significant while the changes in interest and recognition by self were not. The Wilcoxon test showed a significant gain in recognition by others, although the independent t-test did not.

TABLE II. CHANGES IN STEM IDENTITY

| **Scale** | **Pre** | | **Post** | | **t-test (17)** |
|---|---|---|---|---|---|
| | *M* | *SD* | *M* | *SD* | *sig.* |
| Efficacy | 3.2 | 0.3 | 3.8 | 0.3 | 0.03 |
| Interest | 3.6 | 0.4 | 3.6 | 0.5 | 0.62 |
| Self-recognition | 3.0 | 0.5 | 3.2 | 0.1 | 0.63 |
| Others' recognition | 3.0 | 0.4 | 3.5 | 0.5 | 0.15 |

These results suggest students gained confidence and possibly felt like they were perceived as STEM people, but that their more self-oriented attitudes of interest and importance of STEM to themselves was not affected.

Our interview data are still being analyzed. We will add themes and additional findings from those results by the final paper. One important early take away from the interviews was that students wanted to extend their learning about water and wastewater to agricultural applications. Perhaps by extending the lab-based lessons with student-driven research projects in applied settings, which is a goal of the project, we will see more shifts in students' perceptions of interest and self-recognition of a STEM identity.

## V. Future Directions

In our first year of the project, our focus was on adapting and developing relevant lessons on the key water-related literacies we sought to emphasize. Additional extensions will be incorporated in the second year of the project. This includes a visit to a pilot septic system project that is funded by the state EPA and related agencies. This system incorporates a kind of neighborhood-level water treatment technology to augment traditional septic systems to reduce the amount of bacteria and other contaminants released into leach fields. The engineers involved in this project are leaders in this effort and can connect the wastewater topics to this novel technological solution.

We also plan to expand the opportunity for students to conduct their own research projects. As a culminating activity, we intend for students to meet with community leaders to share their learning and make recommendations regarding how to improve wastewater management within their community. Based on student interviews, we are planning for student interest in agricultural science and a few other directions, such as human health and nutrition, that students may want to take the research projects in the future.

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