Creating an Atmosphere for STEM Literacy in the Rural South Through Student-Collected Weather Data

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ABSTRACT

This paper is an examination of a teacher professional development program in northeast Louisiana, that provided 30 teachers and their students with the technology, skills, and content knowledge to collect data and explore weather trends. Data were collected from both continuous monitoring weather stations and simple school-based weather stations to better understand core disciplinary ideas connecting Life and Earth sciences. Using a curricular model that combines experiential and place-based educational approaches to create a rich and relevant atmosphere for STEM learning, the goal of the program was to empower teachers and their students to engage in ongoing data collection analysis that could contribute to greater understanding and ownership of the environment at the local and regional level. The program team used a mixed-methodological approach that examined implementation at the site level and student impact. Analysis of teacher and student surveys, teacher interviews and classroom observation data suggest that the level of implementation of the program related directly to the ways in which students were using the weather data to develop STEM literacy. In particular, making meaning out of the data by studying patterns, interpreting the numbers, and comparing with long-term data from other sites seemed to drive critical thinking and STEM literacy in those classrooms that fully implemented the program. Findings also suggest that the project has the potential to address the unique needs of traditionally underserved students in the rural south, most notably, those students in high-needs rural settings that rely on an agrarian economy. © *2015 National Association of Geoscience Teachers*. [DOI: 10.5408/13-066.1]

Key words: STEM literacy, place-based education

INTRODUCTION

> *"I put the weather station right in between our garden and the cotton field next to the school . . . we use the data from the weather station with the garden that we are working on and then our parents use it in the cotton field for their crops."*
>
> *Theresa Do, middle school teacher*

Ms. Do is one of 30 middle school teachers from rural parishes in northeast Louisiana that participated in a professional development program that provided teachers and their students the methods and materials to collect and analyze data from large-scale and school-based weather stations as a way to support student literacy in STEM (science, technology, engineering, and math). Her school is located in one of the poorest regions of one of the poorest states in the United States.

> *"Demographics make a difference in terms of learning because of resources. Especially in science—it is all about technology and how it can be relevant and used in every life." (Do)*

The program uses a curricular model that combines experiential and place-based educational approaches to create a rich and relevant atmosphere for STEM learning that has the potential to engage traditionally underserved students in the rural south. This model is particularly salient as new national standards are adopted for teaching Science in K–12 education. The Next Generation Science Standards (NGSS Lead States, 2013) highlights the importance of students collecting data and analyzing claims and evidence within a real-world context. "Experiential education is a process through which a learner constructs knowledge, skill, and value from direct experiences" (Proudman, 1995, 1–2). A critical element of experiential education is a shift in the locus of control from the teacher to the learner, as she or he directly experiences authentic learning tasks. The role of teacher becomes that of architect and coach, creating the structures and support that facilitate learning in a dynamic real-world setting.

Place-based education (PBE) aligns pedagogically with an experiential approach, but situates the direct experiences geographically and culturally. Place-based science education has proven to be a successful approach for engaging diverse learners in meaningful scientific inquiry, and has been advocated for its relevance and potential to attract under-represented groups to science (Emekauwa, 2004; Lim and Calabrese Barton, 2006). The approach grounds scientific concepts in the student's own environment, and actively engages students in the collection of local data to address local issues (Sobel, 2005; Smith, 2007). Key characteristics of PBE include an interdisciplinary approach to curriculum development, a focus on activities that "cross boundaries between the school and community," and a charge for students to "become the creators of knowledge" (Woodhouse & Knapp, 2000, 242).

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Funded by Louisiana Systemic Initiatives Program (LaSIP), faculty from the disciplines of education, biology and atmospheric sciences at the University of Louisiana at Monroe (ULM) developed a field-based science teacher professional development program, Out Standing in the Field (OSF), for area middle school teachers. The professional development program, carried out in two phases, leveraged local natural resources by taking middle school teachers and students into the field to do hands-on science investigations in life and Earth sciences.

During Phase I of the program (LaSIP 10-210-ULM-8), 25 middle school teachers were taken to local research sites (e.g., Black Bayou Lake National Wildlife Refuge and Restoration Park, West Monroe, LA) to work side-by-side with scientists with ongoing research at these sites. This collaboration provided teachers with local environmental data that could be used to develop lessons and activities both in the field and in the classroom. This phase took teachers and students out of their classrooms and introduced them to the real-world science carried out in their local ecosystems.

Phase II (LaSIP 12-212-ULM-S) was designed to complement Phase I. This phase brought the field back to the school site by providing teachers and middle school students with the methods and materials to establish a weather station at their respective schools. They could now collect and analyze data from their own school-based weather stations and compare their data to those of the permanent stations located in the field. All participating schools had remote access to field data from two research sites. Basic meteorological data was used to better connect core disciplinary ideas in life science (LS2: Ecosystems: Interactions) and Earth science (ESS2: Earth's systems).

In this paper, we focus on Phase II of the teacher professional development initiative in northeast Louisiana, which provided teachers and their students with the technology, skills, and content knowledge to collect data and explore trends, both from continuous monitoring weather stations (Vantage Pro2; Davis Instruments, Hayward, CA) and simple school-based weather stations, to better understand core disciplinary ideas connecting life and Earth sciences (National Research Council, 2011). In addition, the focus on instrumentation, proper handling, reading of the instruments, and factor-reading errors introduced students to the core idea, PS4C, in physical sciences.

Program Rationale

With 17.6% of its population falling below the poverty line, Louisiana has the second-highest poverty rate in the United States. Moreover, some of the worst poverty rates cluster in the program area, where 33.4% of the population lives below the poverty line (U.S. Census Bureau, 2010). In several of the middle schools involved in the program, 93% of the students qualify for free and reduced-price lunch, compared to a state average of 61%. All schools in the program are categorized as high-need by the state, with an average of 80% of the students qualifying for free and reduced-price lunch. In addition, many of the schools have high minority populations (60%–98% African American) and are predominantly located in rural settings. Student achievement in most schools lags behind the state average. For the past five years (2006–2011), the percentage of middle school students who scored at or above basic in science (29%–54%) in the program schools was consistently below the state average (53%–62%), as measured by the state standardized tests, LEAP and iLEAP, in the areas of science and math (Louisiana Department of Education, 2011).

While northeast Louisiana ranks as one of the poorest regions economically and academically (Dreilinger, 2013), it is rich in natural resources and has a unique ecosystem (Creasman et al., 1992), making the region attractive for teams of local, national, and international scientists to conduct research in the area. Parts of Phases I and II drew on funding from Louisiana Systemic Initiatives Program (LaSIP) to enrich the educational lives of middle school students by providing field-based science investigations at two local research sites—Black Bayou Lake National Wildlife Refuge (Black Bayou) and Restoration Park, West Monroe. Black Bayou is an urban refuge with a 1,600-acre shallow lake with cypress, riparian areas, and upland mixed pine habitat for wetland-dependent fish and wildlife. The other site, Restoration Park, used to be a strip mine that has been restored to a functioning wetland. This wetland system now controls flooding from heavy storms in the West Monroe industrial area. Due to its proximity to the university, ULM science faculty have several long-term research projects running in both sites. Therefore, these sites serve as ideal platforms for unique educational, research, and recreational opportunities for faculty and schools in the community.

PROGRAM DESCRIPTION

In Phase I, 30 middle school teachers joined four university faculty to collect data at three research sites (Black Bayou Lake National Wildlife Refuge, Restoration Park, and Poverty Point State Historic Site). Data were brought into the classroom through inquiry-based activities that were developed collaboratively as part of the program. Phase I of the professional development program had participation satisfaction rates of 95%–100%, and showed significant growth ($p < 0.05$) in those areas relating to scientific ($\bar{x} = 17.46\%$, $n = 30$) and pedagogical ($\bar{x} = 27.50\%$, $n = 30$) knowledge, as well as total knowledge in Earth and life sciences ($\bar{x} = 11.64\%$, $n = 30$). One major lesson learned from Phase I was that teachers were less successful in bringing the rich data-gathering activities and visual artifacts from the field into the classroom and creating substantive experiences for students out in the field. Classroom observation data suggested that teachers in the program would have benefited from more school-based data-gathering activities and the technological support to integrate these and local research data into classroom lessons. In addition, the advent of the Next Generation of Science Standards (NGSS Lead States, 2013) emphasizes scientific practices, such as looking for patterns in the data about natural systems (MS-ESS2-3). In addition to the main Disciplinary Core Ideas for Life Science LS2.A (interdependent relationships in ecosystems) and Earth Science ESS2.D (weather and climate), Science and Engineering Practices included planning and carrying out scientific data collection and producing data as evidence to answer scientific questions, as well as doing simple analyses and interpreting the meaning of collected data. Together, these benchmarks provided clarity and cohesion for the follow-up program of Phase II.

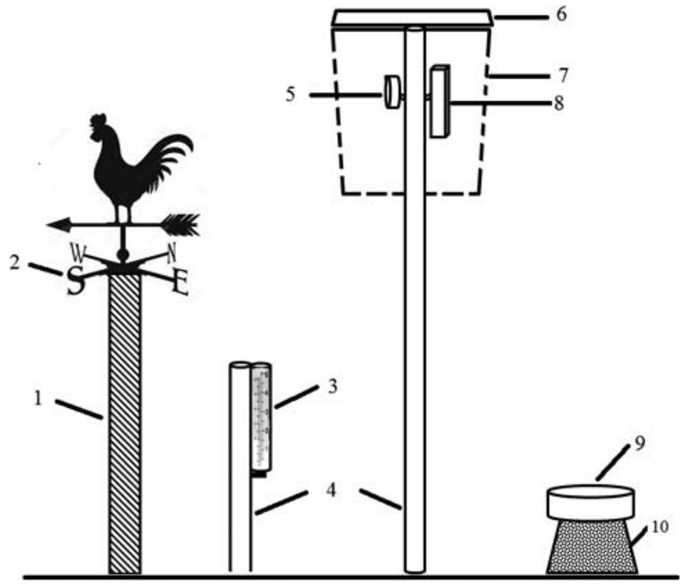

FIGURE 1: A complete weather station built from commonly available material (see text for details) and basic instruments used for measuring weather variables. 1. Wooden plank (2 × 6 in.), 2. Wind vane, 3. Rain gauge, 4. PVC pipe (3 in. diameter), 5. Hygrometer-Barometer combo, 6. Top cover (removable for observations), 7. Modified Stevenson's screen with holes punched all around for air circulation, 8. Min-max thermometer, 9. Evaporation pan, 10. Pedestal (block of wood).

Program Goal and Objectives

The main goal of Phase II was to empower teachers and their students to engage in ongoing data collection that could contribute to greater understanding of the environment at the local and regional levels using school-based weather stations and a shared database with other schools. The need for a more local data collection site was highlighted during Phase I of the program. Phase II employed the central idea of building a simple weather station outfitted with basic instruments including a min–max thermometer, a lux meter, a hygrometer–barometer unit, a rain gauge, an anemometer, an evaporation pan, and a wind vane. This suite of instruments recorded data on environmental variables such as temperature, relative humidity, wind speed, wind direction, precipitation, evaporation rate, and light intensity. Most of these instruments were kept in the classroom and students would be required to bring them along when visiting their weather station for observations and data collection. The min–max thermometer and the hygrometer–barometer unit were housed in a modified Stevenson's screen. The modified screen consisted of a five-gallon bucket mounted on a PVC pole. There were several holes drilled on the side of the bucket to allow air circulation. The PVC pipe passed all the way through the top of the bucket, allowing a steady mount for the bucket itself and a place to attach the min–max thermometer and the hygrometer–barometer unit (Fig. 1). The approximate cost of the entire weather station and the suite of instruments was about $150 at the time the program was carried out.

Workshop Activities

During the professional development workshops, focus was placed on instrumentation with an emphasis on scientific accuracy and the correct way to use instruments and report data. Teachers were also introduced to the concept of *mesonet*—a collective effort in gathering data at several locations that can provide scientists with a better understanding of local weather phenomena such as rainfall patterns in the area, temperature variations, and so forth. Student-collected data from all schools were to be electronically sent to the Central Data Repository (CDR) set up at the university. The purpose of the CDR was to allow students and teachers from contributing schools to have access to data collected by students from other schools, and the data collected from real-world research projects at the two local research sites (Fig. 2).

During workshops, teachers were introduced to the fact that the data obtained is only as accurate as the instrument measuring it; therefore, it is essential to understand the instrument and errors associated with it. Weather variables were studied from several perspectives including function, instrumentation, data collection, basic analysis, and observation of trends, which were then tied across activities in physical and life sciences. This form of engagement and collaboration provided teachers with a deep understanding of site-to-site variations in microclimates and their relationship with environmental, ecological, physical, and Earth sciences.

The program presented 80 hours of professional development over the course of one year (AY 2012–2013). Beginning with a 7-day, 60-hour summer workshop in which middle school life and physical science teachers collected data at two local research sites. Teachers created their own data collection systems, built weather stations using a modified Stevenson's screen for their school site, and retrieved and compared data from both systems as part of classroom lessons (Fig. 3). The first two academic year workshops focused on the ways in which the program might meet the requirements of the Common Core State Standards (CCSS) in English Language Arts and Mathematics. The next two workshops focused on creating and expanding a microclimate mesonet, in which student groups from each participating school generated local weather data, uploaded it to the Central Data Repository and downloaded data from other sites. Finally, a third weather station was set up at a local 150-acre natural park (Kiroli Park) with contrasting ecosystems within its boundaries, to capture a wide range of microclimatic variations in contrasting habitats.

The summer workshop provided an opportunity for teachers to spend a day at each research site and learn how to download, manage and use long-term data sets. At Black Bayou, teachers learned to analyze data (estimate central tendencies and use basic regression) and observed trends that they could use in their classrooms to discuss several concepts in life sciences, such as distribution of plants based on microclimates. Teachers were also introduced to two methods of observation and data collection: (1) a vegetation plot (1 m × 1 m) with an overlaid grid to help teachers identify and quantify the species present by ocular inspection and the percentage cover by each species; and (2) a water sampling technique, using LaMotte water sampling kits, that tested for dissolved oxygen, biochemical oxygen demand, pH, nitrates, phosphates, and lead at different geographical

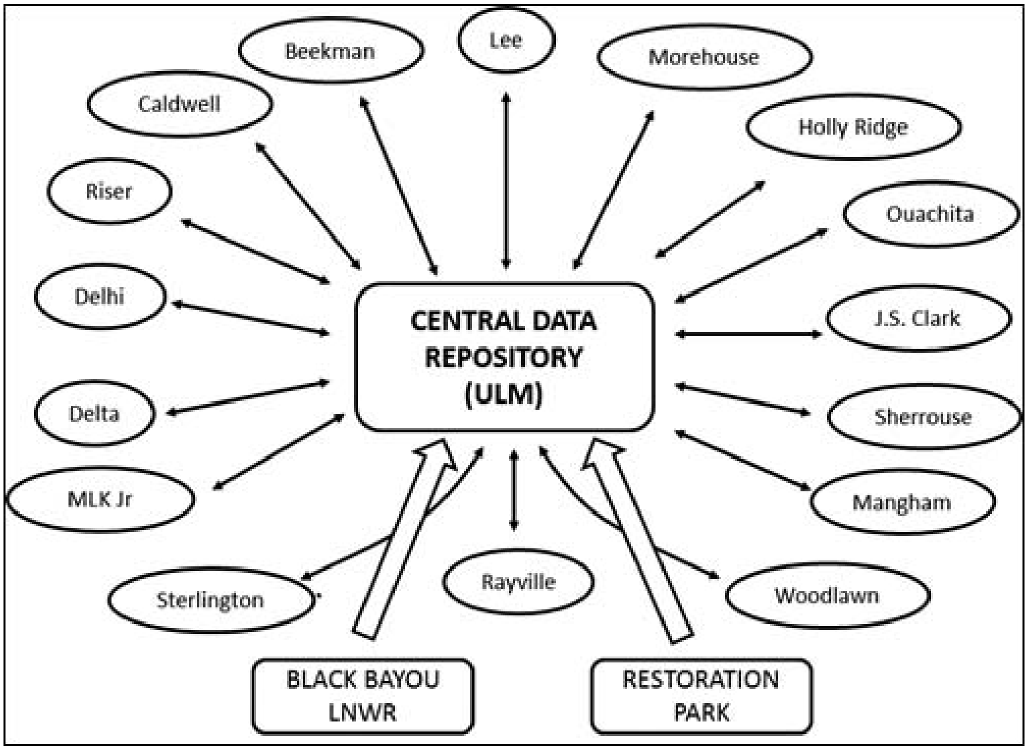

FIGURE 2: Schematic showing the main concept of data sharing and transfer among schools, and between university (CDR) and schools.

points within the Bayou. Teachers used the results to predict the type of organisms that may be present at each specific site.

At Restoration Park, teachers were asked to distinguish the differences between microclimates by collecting data such as temperature, dew point temperature, and evaporation rates. These environmental variables were discussed and compared to readings obtained from Black Bayou so that teachers might discover how different surface heterogeneities result in different microclimates. This realization also served as a springboard into conversations about what creates different microclimates and highlighted the need for

FIGURE 3: Assembling the weather station during the Teacher Professional Development Workshop at the University of Louisiana–Monroe.

an analogous observation station for data collection at their school site. At Restoration Park, teachers were also introduced to two more experimental techniques that helped them understand the complex relationships within a microclimate: (1) measuring the height (using goniometry and verifying the results using a clinometer) and diameter (using diameter at breast height and measuring tapes) of trees at various geographical points to examine patterns in growth and canopy structure (using a densiometer); and (2) measuring cloud height using a simple formula (cloud base altitude = [temperature − dew point / 4.5 × 1,000] + measure station altitude), to make connections between water in the atmosphere and the cloud height. At both research sites, teachers worked closely with university scientists and downloaded data from university deployed automated weather stations.

On the third day of the workshop, teachers returned to the university campus to build their own weather stations from materials provided to them. The completed weather stations were then placed at various locations on the campus, allowing teachers to practice the process of data collection that they will require of their students at their respective school sites. The next day, teachers retrieved the data from their own weather stations, and downloaded data from one of the research sites. The final two days of the workshop, teachers worked in teams with faculty to create technology-enhanced activities that utilized remote and local data, as well as generate a plan to install and use the weather station at their site. The final day took teachers back out into the field to demonstrate the proper installation of the weather station at a local school site.

As noted earlier, academic year follow-up consisted of four 5-hour Saturday mini-workshops. The main emphasis of the mini-workshops was to forge a cross-disciplinary approach to integrating weather data into subjects such as mathematics and English language arts. ULM faculty also served as mentors via a collaborative website on Moodle, which served as a clearinghouse for student-collected data and data from research sites, as well as a forum for questions for faculty and feedback from the field.

Program Evaluation

Although 30 middle school teachers participated in the summer workshop, 28 teachers completed the full program (80 hours). Of these, 30% of the teachers taught exclusively Life Science, and the remaining 70% taught a combination of life and physical sciences. Most teachers (70%) taught a combination of grades at the middle school level (e.g., 6th, 7th, and 8th grades) within a student age range of 11–13 years, while those who focused on life science were at the 7th grade level teaching students ages 12–13 years. Teachers who completed the program were drawn from five parishes, which is the Louisiana equivalent of counties, and represented 15 schools. They were overwhelmingly female (86%) and the majority (65%) self-identified as White. They represented schools that ranged in need from a low of 63% students eligible for free and reduced lunch (FRL) to a high of 94% FRL, and an average of 85% FRL across the 15 sites. Two-thirds of the 15 sites were majority African American students, ranging from 60% to 98% of the students, with an average of 79% across the 10 sites. Using the government's definition of "rural" as "nonmetropolitan (nonmetro) areas that are less than 50,000 in population" (Office of Management and Budget, 2013), all schools in the program are categorized as rural.

To gauge levels of satisfaction with the program, impact on teacher learning and the ways in which the program was implemented in the classroom, the faculty team administered online surveys to teachers twice during the program, in fall of 2012 and spring of 2013. These self-report data were triangulated with classroom-level weather data that were posted to the program Web site, as well as classroom observations at three representative school sites as part of a multiple case study conducted by an external evaluator. A few teachers were also able to administer student surveys (designed by the university faculty), which was not required but encouraged. In all, there were 102 students from two sites that took the student survey. Findings from the case study provided a context for a final round of data collection that included in-depth interviews with a sample of program participants ($n = 10$) and an end-of-program teacher survey ($n = 18$). The internal consistency index, standardized Cronbach's α, of reliability of the survey questionnaire for the teachers was calculated to be 0.92, and that for the student survey questionnaire was calculated to be 0.74. Both of these values were above the generally accepted cutoff value of 0.70 (Nunnally and Bernstein, 1994). The next section describes the parameters and methodological approach of the related case study, and the ways in which the findings informed and refocused this study.

Multiple Case Study

In Phase I, a member of the coordinating team for the program visited every classroom in participating schools and used a state-mandated site observation protocol to assess levels of the implementation. Not surprisingly, every teacher fully implemented the program during the scheduled visit. In Phase II, the coordinating team enlisted the services of a third party researcher to examine the ways in which the program was implemented in the classroom and the subtle impacts on teacher perceptions and student learning in science.

To obtain a cross section of program participants, three sites were selected with an eye to maximum variability relating to setting and levels of teacher buy-in, which was based on faculty perceptions of the teacher interaction and feedback during summer and academic year workshops and the pattern of weather data uploaded to the university website. Student demographics and school structure also varied across sites. The first site is an alternative K–8 school setting with primarily African American students (96% AA; 85% FRL) that rotated into a new class every six weeks. The second site is a traditional junior high situated in an affluent neighborhood with a diverse group of students (68% AA; 63% FRL) that are achieving according to state standards. The third site, a small middle school that resides in the poorest section of the city, is almost all African American students and considered failing by state standards (98% AA; 93% FRL). All three sites were selected from the same school district of a city in which 36% of the population lives below the poverty line. Each case study consisted of an initial observation, selection of two to three students from each setting, administering pre surveys to the teacher and selected students, interviewing the teacher and students, observing students both in the field and classroom, and administering a post survey to students and teachers.

DATA COLLECTION AND ANALYSIS

Data were collected at the end of the Phase II, with teachers ($n = 18$) and, when possible, their students who completed the full program. The central questions of this multicase study were: (1) In what ways are the core ideas of the program being implemented at the site level (school)?; and (2) What is the impact of the program on students and teachers? An open-ended interview protocol was used to elicit teachers' perceptions of student population and classroom/field interactions, implementation of the weather station program, outcomes and challenges faced, and lessons learned during the process. All interviews were conducted by a third-party researcher and were coded for confidentiality. At two sites, teachers were able to administer a student survey that examined student achievement, interest and motivation in the program and specific knowledge gained from the program. These data were then triangulated with teacher survey data, which included several open-ended items describing the student experience in the classroom as well as the impact of the program on the larger community. Student and teacher surveys included parallel items relating to perceived impact of the program on students' STEM literacy.

A constant comparative method was used to code all interviews and survey items, and to generate a list of themes that seemed to relate to level of classroom implementation of the program (Miles,Huberman, and Saldaña, 2013). A total of seven themes represent factors, or indicators, of how the program is being implemented at a school site: (1) student motivation, (2) geographical location, (3) student background, (4) student attitude, (5) data collection practices, (6) integration into curriculum, and (7) teacher professional development goals (Fig. 4). Using this approach, descriptors for high, medium, and low levels of implementation were developed (Fig. 4) and were used as a rubric for assessment and program completion by all participating schools ($n = 10$).

In addition to the qualitative analysis, researchers used a regression analysis (SAS® 9.2) to determine what variables explained the learning gains the most. This would allow examination of any relation between level of implementation and student learning, with respect to STEM literacy. The four predictor variables were whether the student was: (1) an active part of the data collection process (ACT), (2) was interested in working with the weather station (INT); (3) used the information in other subjects (USE), and (4) gained knowledge from the experience as measured by a standard instrument (SAV). These data were obtained from student surveys ($n = 102$) at only two sites because either other sites did not submit data on time for the current analysis and/or there were not enough student surveys to conduct meaningful analysis.

FINDINGS

Preliminary findings from the multicase study suggested, that although teachers at most school sites had accepted the innovation with an overall positive attitude, there were disparate levels of performance among students, both within the individual sites and across the sites. Analysis of teacher and student survey data and teacher interview data suggest that the level of implementation of the program (high implementation, HI; medium implementation, MI; low implementation, LI) related directly to the ways in which students were using the weather data to develop STEM literacy (see Fig. 4, levels of implementation). In particular, making meaning out of the data by studying patterns, interpreting the numbers and comparing with long-term continuous data from the CDR at the university or data from other school sites seemed to drive critical thinking and STEM literacy in those classrooms that fully implemented the program (HI).

Student interest and engagement was a critical factor in determining the level of implementation of the program at the site level. Teacher interview and student survey data suggested that students were often engaged because of a strong student/teacher relationship that was rooted in trust. A student from a HI site noted that

> *"you need to know this stuff. Our teacher would not give us something we don't need to know!"*

Many students simply liked to get out of the classroom,

> *"because it is always interesting to go outside for a change instead of the classroom. I like being able to participate in it."*

One student valued "doing science" and reported that,

> *"I love when we go out to the station because we get to do hands-on science."*

Other students were eager to learn about the set of tools and instrumentation of this "cool" device. One student described what s/he had learned from working on the weather station as

> *"learning how to make the right percent and learning how to use the new instruments."*

The overwhelming majority of teachers (80%; $n = 10$) in sites that regularly collected daily data with more than half of their students (HI) noted that students in classes that collected data were "very interested" in the program, and over half of these teachers (60%) felt that students in other classes were also "interested" in the program:

> *"Students in other classes wanted to become part of our project and change their schedules."*

These same teachers noted that students who collected daily data over a period of time began to make connections beyond the classroom:

> *"My students who worked on this became very interested in the climate of our state. They started questioning the weird temperatures we were getting and were curious if we were seeing a change in the seasons."*

Teachers at these sites listed the interaction with "real" scientists, and "real world opportunity for them to collect, record, and present data" as motivators for students.

Whether a site was located in a small city or rural and agrarian community, also seemed to play a role in the level of implementation of the program. Findings from HI sites suggest that meaningful discussion and greater involvement with the weather data was one of the most important means

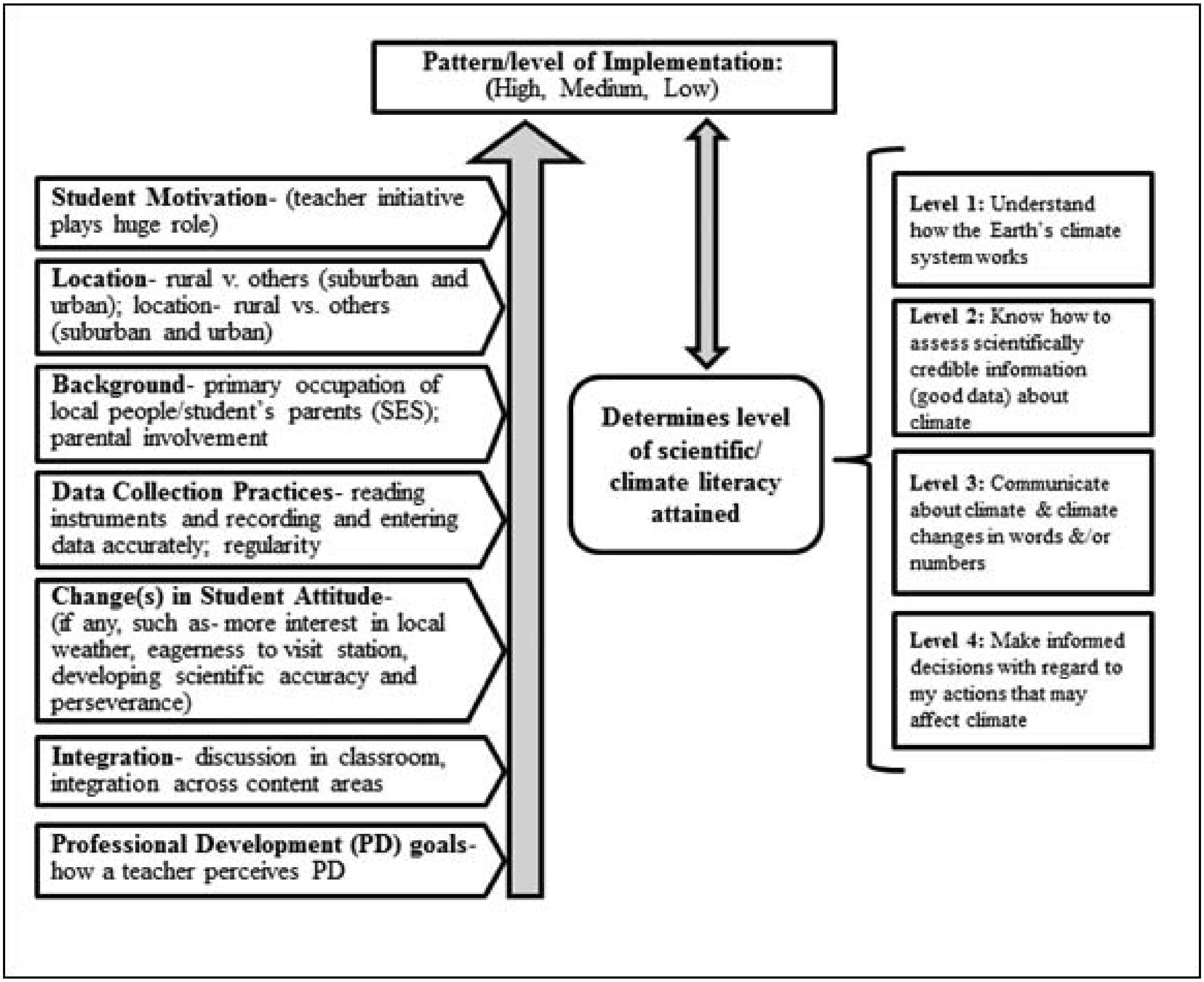

FIGURE 4: Conceptual framework for Phase II, showing the levels of implementation and the predicted student-learning outcome.

to establish seamless connections between the weather and its influences on the local vegetation, area farms, and students' lives. For example, one teacher at a rurally located HI site described the students' relation to their local environment:

> *"All they know is logging, cut down trees, make money!"*

But, after students were introduced to the weather station and had regularly collected data, the teacher reported that some students became more interested in knowing about the place in which they lived:

> *"We looked at the plants and animals (thriving/living) in the wooded area behind the school . . . we talked about microhabitats and things like that."*

Many teachers noted the need for parental involvement and knowledge as a necessary component for students' motivation and ability to make connections between the curriculum and themselves:

> *"Parental involvement and background makes a difference in the nature of [student] involvement. Most of the parents do not have the background to really communicate with them. They [students] really don't have anybody to ask a question about this."*

As noted earlier, all the schools in the program were classified as high-need, with an average of 80% of the students qualifying for free and reduced lunch; however, the program seemed to be a good fit with the population:

> *"I think the program deeply affected some of my kids—they loved having hands on, being able to go outside, do something, showing they were making a difference."*

Teachers in HI sites also noted a ripple effect at home:

"I had a few parents tell me about their child's interest in the weather station when they came home."

Student attitude towards using the weather station and its implications on their daily lives seemed to shift positively in those sites where the program was fully implemented. Teachers at HI sites reported a range of somewhat to profound changes in student attitude:

"We collected the data and worked on it, that was great, but their change in attitude is the biggest reward from this project!"

Teachers at HI sites noted shifts in student achievement and ability to make connections between the curriculum, the local environment and themselves. One HI teacher mentioned that some students'

"scores went up exponentially in physical science just from letting them use the tools!"

S/he also observed a greater involvement of students with the weather and its effect on their family lives:

"Earlier they would not care what their parents said [about the weather] but now it's like—oh my dad is a farmer, he can use this stuff [the weather data]."

Another HI teacher noted a career connection:

"They were so excited and they are interested, and now they have been looking more at weather stuff . . . they want to be a meteorologist one day."

At MI sites where only a few students were involved in the program, teachers also noted shifts in attitude:

"It was almost a jealousy thing, those six students took ownership of it [monitoring and recording data from the weather station] and they didn't want anybody else going out there collecting their data."

Even an LI teacher whose students seldom collected data but looked at weather data that was collected by another teacher's class at the same site mentioned,

"It's [still] their data and their weather station, as opposed to reading something abstract, or [working on] abstract numbers from the book."

Student survey data support teachers' perceptions of shifts in student interest. Several students at HI sites mentioned the new skill of collecting data as a motivator:

"I love going out to check the weather and use the instruments."

Specifically, students were interested in the instrumentation used in the weather station and "how those things can do what they can do." Several students mentioned being able to convert temperature units from degrees Fahrenheit to degrees Celsius and being able to read the thermometer and the rain gauge as motivators. Other students emphasized the practical importance of the weather station and that,

"it helped to judge how much rain fell and where a storm is."

Data collection practices (Fig. 5) and whether the data were uploaded to the program website were decisive factors in determining the level of implementation. Although 70% of school sites reported regular data collection at their school sites and uploaded the data into the university-provided Web site, the level of implementation at the sites seemed to affect the ways in which students used the data collected. At HI sites (30%), teachers described their students' daily or weekly data collection and how students "made sense" of the data by plotting and looking at patterns/trends or comparing their data with other school sites and the larger dataset that they could access on the university Web site. Teachers at MI sites (40%) reported more emphasis on the process of regular and accurate data collection and students learning to take responsibility and ownership of not only data collection but also keeping track of their work and uploading their data to the university Web site. Notably, teachers at LI sites (30%) reported minimal activity with the weather station, typically recording weather data on their own with one or two accompanying students or sometimes none, and doing little with it other than occasionally uploading it to the university Web site.

Student survey data from HI sites support teachers' descriptions of the process of data collection, but a few differed in the perception of the purpose of the program:

"I don't care that much about it. What's the point? We have the news."

Some students expressed their lack of satisfaction and desire to do more with the weather station:

"Some things I did not understand but if I worked with it more often I would . . . be more interested."

Integration into curriculum**,** and the ways that teachers connected the weather data to science content, partially determined the level of implementation of the program. Findings from HI sites suggest that meaningful discussion in the classroom and greater involvement with the weather data by all students was one of the most important means to establish seamless connections between the weather and its influences on the local vegetation, local gardens, and everyday life in general. At these sites, all (100%) of the teachers posted the weather data in a public place, most (80%) of the teachers taught a unit and/or individual lessons dedicated to weather, and a few (20%) used the weather data set for non-weather-related activities. At MI sites, the majority of teachers (72%) also taught units and lessons related to weather, but did not publicly post the data or use it in ways beyond the weather-related units and lessons. Almost no curriculum integration was achieved at LI sites, where the weather station program was mostly implemented as an extra resource and not part of the regular classroom learning activities.

Teacher interview data provided insight into the gradations of curriculum integration and the perceived impact on student critical thinking. A few teachers (30%)

FIGURE 5: Middle school students at Delta Junior High School, Mer Rouge, LA, collecting data from a min-max thermometer.

at HI sites noted that they had indeed worked with their students on graphing and interpreting the data, but that

> *"students often have problems interpreting graphs although it is taught in the elementary [grades]."*

The same teachers also reported that they were able to compare their data with other school sites and this interested the students immensely, as one teacher phrased it,

> *"they just realized that wow you know, even if we are from this small, little parish, we have an impact on somebody else."*

On the other hand, several teachers at MI sites (40%) mentioned that, although they had managed to establish a classroom routine of collecting data and engaging a core group of students in the process, they could not get to the point where the students could "play" with the data and make sense of it. These teachers reported that they were able to fit the weather station program into the weather unit that was provided as part of the state curriculum.

Program goals for implementing teacher professional development and the type of communication with program faculty seemed to affect the site implementation of the program. All teachers valued the easily accessible communication with the faculty that provided on-demand expertise:

> *"Faculty here was always open, helpful and willing. It didn't matter if I saw them here [at the University] or at the store, I stopped and talked to them."*

These kinds of ad hoc exchanges made it difficult to measure the level of communication of high, medium, and low implementers, but interview data suggest that teachers at different levels of implementation were asking very different questions during these interactions. LI teachers valued the ways in which faculty helped with problem solving for potentially difficult site-specific situations. MI teachers mentioned that the most important information during the workshops was logistical: how to set up the instrumentation, read/record data accurately, and upload the data into the computer. On the other hand, HI teachers seemed to focus more on student impact:

> *"Coming to every workshop helped me help my students with the issues we were facing while doing this project."*

While teachers at all levels of implementation reported that students were developing STEM literacy as a result of the program, it is interesting to note that the level of literacy did not seem to relate to the level of implementation of the program. In an effort to examine more closely what might be the critical variables of the program that help develop STEM literacy, a simple regression analysis was carried out on student-level data collected at two sites that were high implementers. The student surveys ($n = 102$) included three achievement items to assess what students have learned from participating in the program. These items were (1) reading the correct temperature from a thermometer, (2) explaining changes in reading the temperature in a scenario describing a rainfall event, and (3) briefly answering a question asking how they connect the knowledge gained through the program to the science curriculum.

It was found that up to 77.67% students answered all three questions correctly at HI sites. Although no difference was found in the performance of students at the MI site (78%), data suggest that the act of weather data collection may have been practiced and implemented at both HI and MI sites with comparable rigor that resulted in learning. There was not enough student data from LI sites to draw meaningful conclusions.

On the other hand, the regression model exploring factors that influence STEM literacy in a sample of students was significant, $r^2 = 0.46$, $F(4, 96) = 20.49$, $p < 0.001$. As noted earlier, the predictor variables related to student participation in data collection (ACT), interest in the weather station (INT), use of information in other subjects (USE), and learning gains in items related to STEM literacy. ACT had the highest partial r-square in the model, explaining 28% of the variation in CLT, followed by INT, USE, and SAV (11%, 5.1%, and 2.4%, respectively).

Given the age and grade level of the student sample, namely middle school students ages 12–14 years, active participation (ACT) being the most influential variable is not unexpected. Triangulation from classroom observations suggested that teachers that developed an active form of participation and regularity of data collection, maintenance of the station, and data entry were found to engage more students and were actually getting much more done than in the classrooms where the teachers were doing most of the work or were not encouraging regular data collection. The importance of the second variable, student's interest scores (INT) is in congruence with existing literature on science education. Positive attitude towards science, including high level of student interest, can significantly contribute to both immediate and long-term student learning (Markowitz, 2004). Qualitative data from teacher interviews also clearly suggest that student motivation, interest, and engagement are critical factors in helping students develop climate literacy and gain an understanding of the weather. The third variable of importance, USE or students using the knowledge gained through the program in other content areas also signifies the extent to which teachers could facilitate integration of scientific data collection, recording, and interpretation across content areas. Contributing up to 5% of STEM literacy (CLT) score, this also relates to the targeted science and engineering practices mentioned above for simple scientific investigations that students can carry out across content areas. Student achievement (SAV) was ranked the lowest among predictor variables, perhaps due to the limited time of implementation and with the limited scope of assessment.

DISCUSSION AND IMPLICATIONS

When fully implemented, Phase II of the program, Out Standing in the Field, has the potential to increase student literacy and engagement in STEM. While several factors seemed to determine the level of implementation of the program in the classroom, the level and type of student involvement in the program was critical. Those sites where students went beyond merely collecting weather data to connecting that data to their community also had higher levels of student interest and engagement which, in turn, related directly to their STEM literacy.

While the intent of this program was to infuse scientific data collection and instrumentation at the middle school level that was interdisciplinary in nature and could serve as a content bridge for life and physical sciences, the site-based weather station became a concrete example and daily reminder of integrated STEM for teachers and their students. The process of data collection and the content connections provided by the act of collecting data throughout the year, and connecting those data to classroom learning and the community, serve as a compelling preface to demands of the Next Generation Science Standards to integrate STEM disciplines in real and relevant ways (NGSS Lead States, 2013).

Findings also suggest that the program has the potential to address the unique needs of traditionally underserved students in the rural south. Teachers in high-needs schools reported that the program engaged the majority of their students and provided a much-needed hands-on approach to science. Even at the lowest level of implementation, the program increased student interest in science by providing real and immediate data about the students' local environment. Those sites that were situated in rural areas that relied on an agrarian economy were more likely to connect the learning from the weather station to their local environment and often operated at a higher level of implementation. The program surmounted socioeconomic obstacles at several sites by making the student the purveyor of scientific information in their school backyard, as well as providing the skills and motivation for students in historically underrepresented populations to pursue degrees and careers in STEM.

As the program moves into its final phase of funding, it will expand to include an interdisciplinary team of teachers from six of the high-implementation and medium-implementation sites. These teams will include a teacher from English language arts, social studies, and mathematics, in addition to the science teachers involved in Phase II, for the participating schools. The purpose of the interdisciplinary approach is to create the capacity for more regular data collection and deeper connections between core subject areas and the larger scientific community (Fulton and Britton, 2011). By providing a support system of other teachers and students involved in the program, we hope to create an atmosphere for critical conversations that use student-collected weather data to make connections between STEM disciplines and the larger scientific community. When fully implemented, the project furnishes students and teachers with an awareness of the importance, impact, and intricacy of data collection and the ways in which it contributes to greater understanding and ownership of the environment at the local and regional level.

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