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Citizen science in elementary classrooms: a tale of two teachers

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Introduction: Elementary teachers face many challenges when including reform-based science instruction in their classrooms, and some teachers have chosen to enhance their science instruction by introducing students to citizen science (CS) projects. When CS projects are incorporated in formal school settings, students have an opportunity to engage in real-world projects as they collect and make sense of data, yet relatively few CS projects offer substantial guidance for teachers seeking to implement the projects, placing a heavy burden on teacher learning.

Methods: Framed in theory on teacher relationships with curricula, we prepared science standards-aligned educative support materials for two CS projects. We present convergent mixed methods research that examines two teachers' contrasting approaches to including school-based citizen science (SBCS) in their fifth-grade classrooms, each using support materials for one of the two CS projects. Both are veteran teachers at under-resourced Title 1 (an indicator of the high percentage of the students identified as economically disadvantaged) rural schools in the southeastern United States. We document the teachers' interpretations and use of SBCS materials for the CS projects with data from classroom observations, instructional logs, teacher interviews, and student focus groups.

Results: One teacher adapted the materials to include scaffolding to position students for success in data collection and analysis. In contrast, the second teacher adapted the SBCS support materials to maintain a teacher-centered approach to instruction, identifying perceptions of students' limited abilities and limited instructional time as constraining factors.

Discussion: We discuss the intersection of CS projects in formal education and opportunities for engaging students in authentic science data collection, analysis, and sense-making. The two teachers' stories identify the influences of school context and the need for teacher support to encourage elementary teachers' use of SBCS instruction to supplement their science instruction.

KEYWORDS

citizen science, outdoor education, elementary science, educative support materials, school-based citizen science

1 Introduction

When citizen science[1] (CS) projects are incorporated in formal school settings, they offer students opportunities to engage in real-world science projects as they collect and make sense of the data (Jones et al., 2012). Importantly, students' data collection and sharing data with CS projects introduce students to the work of scientists, and students can see themselves as participants in the science community (Esch et al., 2020); yet, relative to the number of CS projects, few projects offer substantial guidance for teachers seeking to implement the projects for instructional purposes, placing a heavy burden on teacher learning. One way to support teachers' implementation of CS is the development of educative curriculum materials (Davis et al., 2017). Educative curricula are "designed to promote teacher learning as well as student learning" (Davis et al., 2014, p. 25) by helping teachers acquire both content knowledge and pedagogical content knowledge (Arias et al., 2016; Davis et al., 2017). The present study is part of a larger research project designed to identify how and what types of support materials for CS projects promote both teacher and student learning. Included in the research goals to enhance science instruction is an emphasis on supporting teachers for moving some of their instruction outdoors. The schoolyard can offer an outdoor learning space that is familiar to students and available for ongoing observations of nature patterns and data collection. While some teachers perceive barriers to moving instruction outdoors such as lack of time, administrative support, or concerns about student behaviors (Patchen et al., 2024), researchers have identified academic and emotional benefits for students (Ayotte-Beaudet et al., 2023; Rios and Brewer, 2014). This research was conducted in elementary (K-5) classrooms in the United States (U.S.) where efforts to address inconsistencies in elementary science instruction are well documented (National Research Council, 2012; NGSS Lead States, 2013).

2 Background

2.1 Elementary science education

Science education is a critical component of a full education beginning in early grades, but many studies have identified wide variations of teachers' science instruction and alignment with reform-based science instruction (Appleton, 2013). Students' experiences with science practices can build a strong foundation for skills that can be applied across all academic areas such as language skills, logic and reasoning, and problem-solving (NGSS Lead States, 2013; National Research Council, 2007). In the U.S., instructional decisions made in response to accountability policies have continued to marginalize science instruction in elementary school grades such that it pales in comparison to mathematics and reading instruction (Plumley, 2019).

Elementary school teachers have described challenges in executing effective science lessons when they lack instructional time, professional development, and high-quality instructional materials (Davis et al., 2006; National Research Council, 2007). Continuous professional development is critical for teachers to support their students' science learning (Wilson, 2013); however, there are limited opportunities for professional development or coaching in science instruction compared to mathematics and literacy (Banilower et al., 2018). In addition, although examples exist for adapting curriculum for local contexts (Barab and Luehmann, 2003; Davis et al., 2006; Millar, 2011), few science curricula are designed to enhance teachers' science content knowledge or offer support for various student needs. Some elementary science curriculum materials tend to emphasize teacher-led or lecture-focused teaching practices, yet research shows that student-centered curricula are more effective for addressing students' misconceptions and supporting students' learning (National Academies of Sciences, Engineering, and Medicine, 2022; National Research Council, 2012; Sesen and Tarhan, 2011).

Due to the challenges elementary school teachers face in science instruction, the sustained science engagement and three-dimensional instruction envisioned in the NGSS has yet to be fully realized (Smith et al., 2022). In response, some teachers have sought to enhance their science instruction by introducing students to CS projects (Boaventura et al., 2021; Hayes et al., 2020). Engaging teachers and their students in CS has the potential to provide three-dimensional science learning opportunities in the context of authentic, project-based science inquiries (Aristeidou et al., 2023; Pizzolato and Tsuji, 2022; Wu and Hsu, 2024).

2.2 Citizen science in classrooms

CS involves individuals in authentic scientific endeavors who are not professional scientists, typically in collaboration with or supervised by professional scientists or scientific institutions. There are over one thousand documented CS projects, but relatively few are designed with classroom application in mind (Abourashed et al., 2021; Ballard et al., 2017; Pizzolato and Tsuji, 2022). Incorporating CS in schools can be a powerful tool for increasing students' access to science, however "developing robust science curricula around citizen-science activities is tremendously challenging" (Bopardikar et al., 2023).

School-based citizen science (SBCS) can (1) provide much-needed science-specific professional learning for elementary teachers (Aristeidou and Herodotou, 2020; Ferreira, 2015; Plumley, 2019; Zhang et al., 2015); (2) engage students with science early (Archer et al., 2010; Murphy et al., 2007); (3) immerse students in nature while their curiosity and interest are high (Sorge, 2007); and (4) connect science with students' lives (Aristeidou et al., 2023). While some question the quality of data collected by non-professionals, studies have found that "high quality scientific and community outcomes are achievable from school-based citizen science initiatives" (Pizzolato and Tsuji, 2022, p. 229). Bonney et al. (2014) found that data collected by trained non-professionals can match the quality of data collected by experts. Similarly, Saunders et al. (2018) note that CS can not only provide "engaging opportunities for learning for students and their teachers but can yield results of sufficient quality to contribute to the peer-reviewed scientific literature" (p. 639).

Researchers of CS in schools document limited applications and discuss areas of need. Pizzolato and Tsuji (2022) looked at the

1 We acknowledge that use of the term "citizen science" is actively debated in the field and that alternatives exist, among them "participatory science" and "community science." We chose "citizen science" for this manuscript partly because it is still the most commonly used term and has widely shared meaning.

frequency and length of CS project implementations in classrooms and found that most SBCS efforts were a one-time occurrence. Other researchers have found that efforts to include CS in classrooms consist primarily of student data collection, and few include opportunities for students to analyze or make sense of the data they collect (Kloetzer et al., 2021; Pizzolato and Tsuji, 2022). In their discussion of research on the implementation of CS projects in K-12 settings, Pizzolato and Tsjui suggest that there is a need for SBCS project initiatives to "have students actively engaged in these citizen science projects beyond being 'citizen-sensors'" (p. 229). SBCS has the potential to move beyond data collection and fully engage students in science practices.

2.3 Educative supports and SBCS

Despite the value of integrating CS projects into K-12 settings, teachers may struggle to find time and curriculum materials to support the implementation of CS in formal classrooms. To address teachers' challenges, we developed educative curriculum support materials (Arias et al., 2016; Davis et al., 2017) for two CS projects: Community Collaborative Rain, Hail, and Snow Network (CoCoRaHS) and Lost Ladybug Project (LLP). In the first year of the larger study, as we developed the support materials, we asked a group of five teachers, our teacher advisory group, to incorporate the two projects in their classrooms *without* additional materials or professional development from our team. In year 2 of the study, we provided support materials to the teacher advisory group and asked them to introduce the SBCS projects to their students and pilot test our materials. We met regularly with the teacher advisory group teachers to discuss their impressions of and feedback on the support materials. Their experiences and recommendations informed revisions to our support materials to better meet elementary school teachers' needs (Carrier et al., 2024). During these pilot study years, we also recruited 50 teachers to incorporate SBCS in their science instruction. In years 3 and 4 of the study, we collected quantitative and qualitative data from teachers and their 5th grade students. In this paper, we present data that were collected in year 3 of the study.

The two CS projects were selected because of their content alignment with the 5th grade science standards (weather and ecosystems) in the state where the study was conducted. CoCoRaHS began in 1998 to expand scientists' data on precipitation trends across the U.S. and other countries. Citizen scientists install a project-specified rain gauge, register their rain gauge as a station with CoCoRaHS, and collect and report their station's daily precipitation amounts on the CoCoRaHS website. Today, there are almost 100,000 stations in and surrounding the U.S. The LLP project began in 2000 because entomologists noted an increase in the numbers of Asian ladybugs (*Harmonia axyridis*) and a decrease in the nine-spotted ladybug (*Coccinella novemnotata*), also called nine-spotted lady beetle or C9. The initial goal of the project was to help scientists survey ladybug populations in New York state. It has since expanded across North America, and citizen scientists collect data on the numbers and types of native and non-native species of ladybugs by uploading pictures and descriptions of ladybugs, weather details, and location where they found the ladybugs onto the project's website.

In addition to the two CS projects' alignment with the state's 5th grade science standards, the projects offer students many opportunities to collect data outdoors (e.g., making observations), connect with nature in their schoolyard, and increase their awareness of natural processes (Schuttler et al., 2018). As the students engage purposefully with nature, there are also opportunities for interdisciplinary connections with subjects beyond science such as language arts (e.g., reading and writing informational text), mathematics (e.g., manipulating data and graphing), and social studies (e.g., mapping). These connections can be especially helpful in elementary schools, where less time during the school day is dedicated to science and social studies (Plumley, 2019). Connecting science across disciplines helps teachers expand their instructional time for science beyond the often-rigid time structures that separate subject area instruction. Importantly, as we developed SBCS materials for these two projects, we were intentional in situating learning in the context of teachers' classrooms and reinforcing teachers as learners (Arias et al., 2016).

2.4 Theoretical framework

We framed our work using Remillard's (2005) theoretical model that examines teachers' relationships with curriculum and the factors that influence their planning and enactment of curriculum. Remillard's framework identifies interactions between the teacher and the curriculum and argues that this "participatory relationship" depends on the teacher and the curriculum. Remillard's work sought to understand how teachers interacted with and used curriculum materials and described teachers as "active users of curriculum materials and shapers of the enacted curriculum" (p. 215). Remillard's model includes "students" and "context," acknowledging that the teacher-curriculum "participatory relationship must be understood as embedded in particular local and global contexts" (p. 238). We adapted Remillard's original model by elevating the focus on *students* and *context* as we examine teacher relationships with curriculum and the factors that inform teachers' instructional decisions and applications of SBCS in elementary school science classrooms (see Figure 1). In this study, we explore the critical role of the teacher in SBCS and contextual influences that encourage and inhibit the accompanying science learning.

As we designed our study of teachers' uptake and implementation of SBCS, we considered contributing factors. The *student* factor includes students' socioemotional needs, socioeconomic status, academic needs, and prior experiences with learning outdoors. The *context* factor includes the school community, district or school priorities, school resources including the schoolyard, the culture of learning, and accountability policies. The *teacher* factor acknowledges an interdependence between school context and teaching practices (Talbert et al., 1993), and a school's culture and socioeconomic level can influence teachers' instructional practices and beliefs (Deemer, 2004; Rubie-Davies et al., 2012). Additional factors that influence teachers' instructional decisions are their own backgrounds and comfort with science content and their approaches for supporting students' learning and needs. Using quantitative and qualitative data, we report on two case study teachers to identify how and which factors within the model contribute to a teacher's relationship with the planned and enacted curriculum.

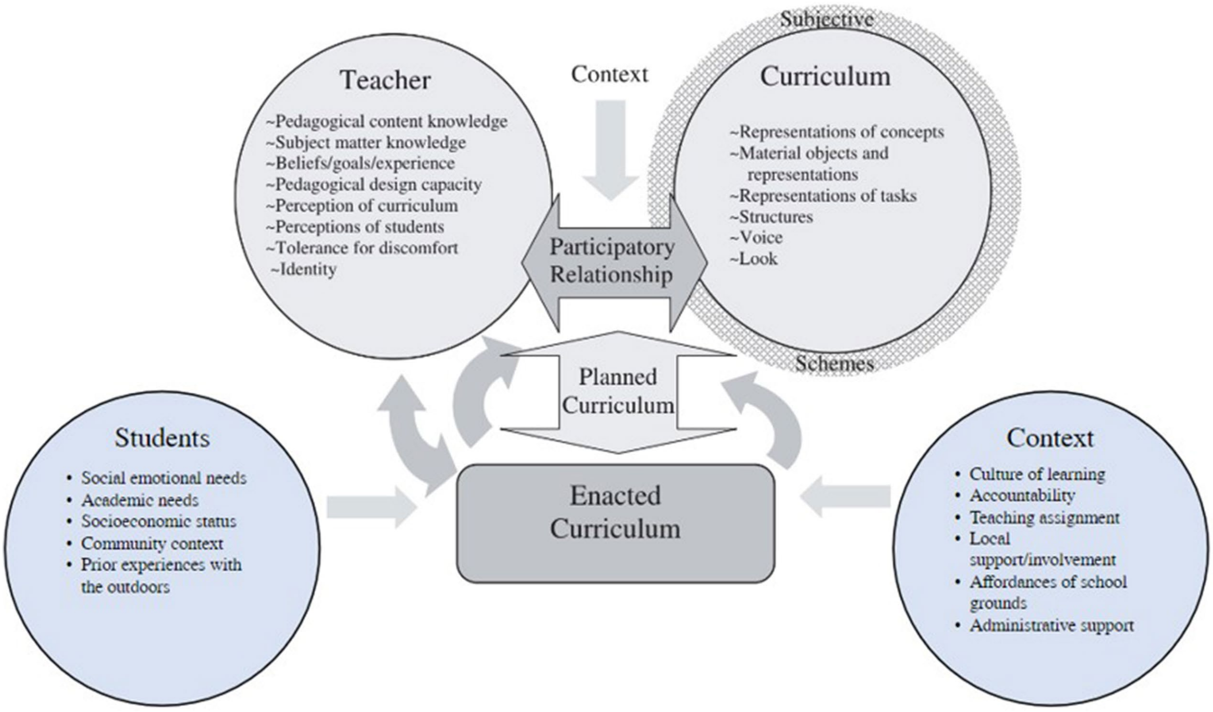

FIGURE 1
The participatory teacher-curriculum relationship (adapted from Remillard, 2005).

2.5 Research questions

In this paper, we present data that document two teachers' implementation of SBCS in their 5th grade classrooms. Both teachers used support materials developed by our research team for one of the two SBCS projects (one had our materials for CoCoRaHS, the other had materials for LLP). We were interested in understanding how two teachers with similar student populations and similar school contexts use our teacher supports and curriculum materials to implement the SBCS projects. Our research questions asked:

1. How do teachers incorporate SBCS projects in their classroom and in the schoolyard?
2. How do teachers navigate their school contexts to include SBCS projects in their science instruction?

3 Methods

This primarily qualitative study (Creswell, 2021; Creswell and Creswell, 2017) is part of a larger 4-year research titled *Teacher Learning for Effective School-Based Citizen Science* (TL4CS). As previously mentioned, the intent of the larger study is to develop instructional materials for CS projects that will support elementary teachers' implementation of SBCS in their classrooms and schoolyards. The 50 study participants were 5th grade teachers from schools in one southeastern state in the United States. We selected 15 of the teacher participants as case study teachers to look more closely at teachers' interpretations of the support materials and their respective approaches to implementing the SBCS projects with their students. In addition to quantitative data, we collected observation, interview, and student focus group qualitative data with these case study teachers. The case study teachers were purposefully selected (Creswell, 2021) to ensure representation across treatment groups (i.e., CS project for which teachers had support materials), geographic regions of the state, and dimensions of school demographics (e.g., percentage of underrepresented students; school affluence; and rural, urban, and suburban locales). The research design for the larger study is shown in Figure 2.

Teacher participants attended a one-day summer professional development where they were introduced to both CoCoRaHS and LLP projects, then were asked to include both CS projects in their science instruction for the entire school year. As with anyone attempting to participate in these CS projects, teacher participants had access to both CS project websites (www.cocorahs.org and www.lostladybug.org). In addition to the CS project websites, we randomly assigned teacher participants to have SBCS materials for one of the CS projects that were accessible to them on our TL4CS website (see Figure 3 for an example of CoCoRaHS SBCS materials). This research design allowed us to document how teachers implemented CS projects in their classrooms with and without support materials. Support materials for each project included monthly activities, content background for teachers, outdoor learning strategies, and content-specific videos and readings for students.

For the present study of two case study participants, we focus primarily on qualitative data collected during the first year that teachers implemented the SBCS projects to document factors identified in the theoretical framework (see Figure 1)—*teachers'* planning and enactment of SBCS using support materials (*curriculum*), *context*, and *student* factors.

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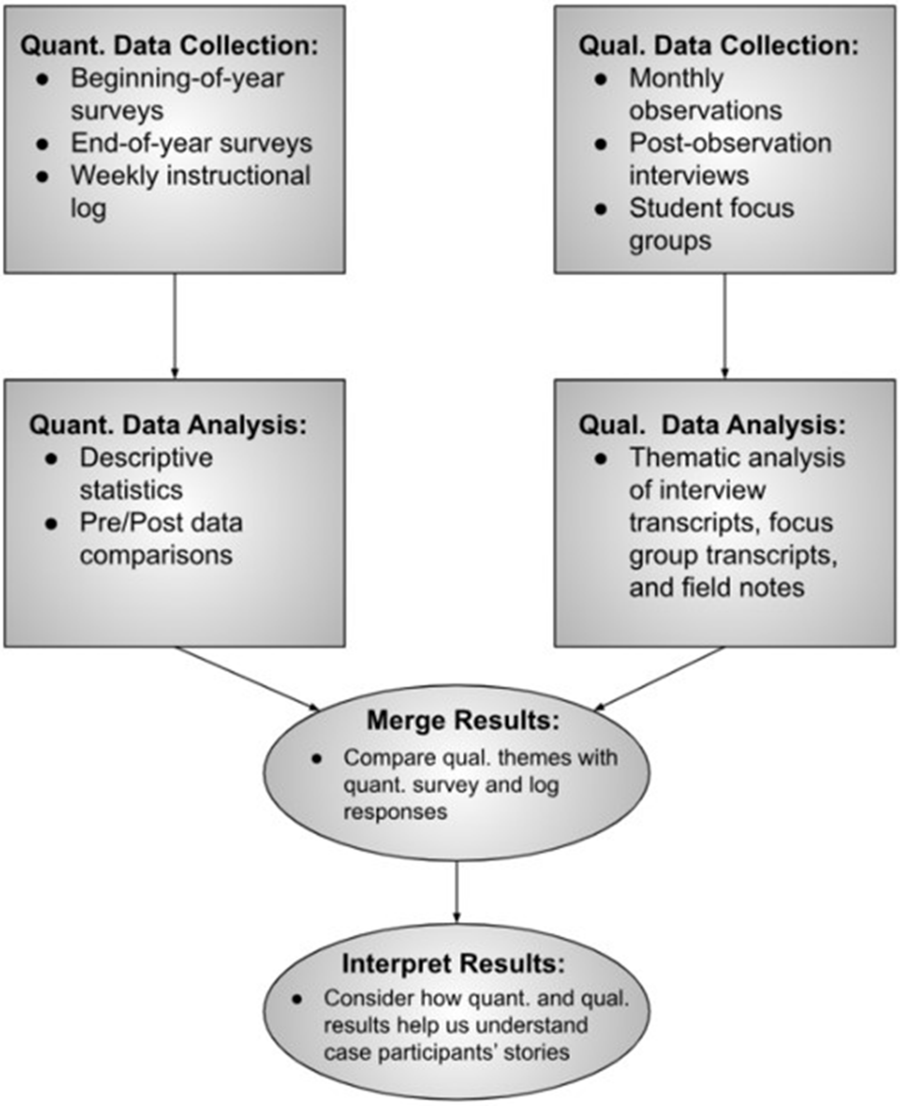


FIGURE 2
Convergent mixed methods design (adapted from Creswell and Clark, 2017).

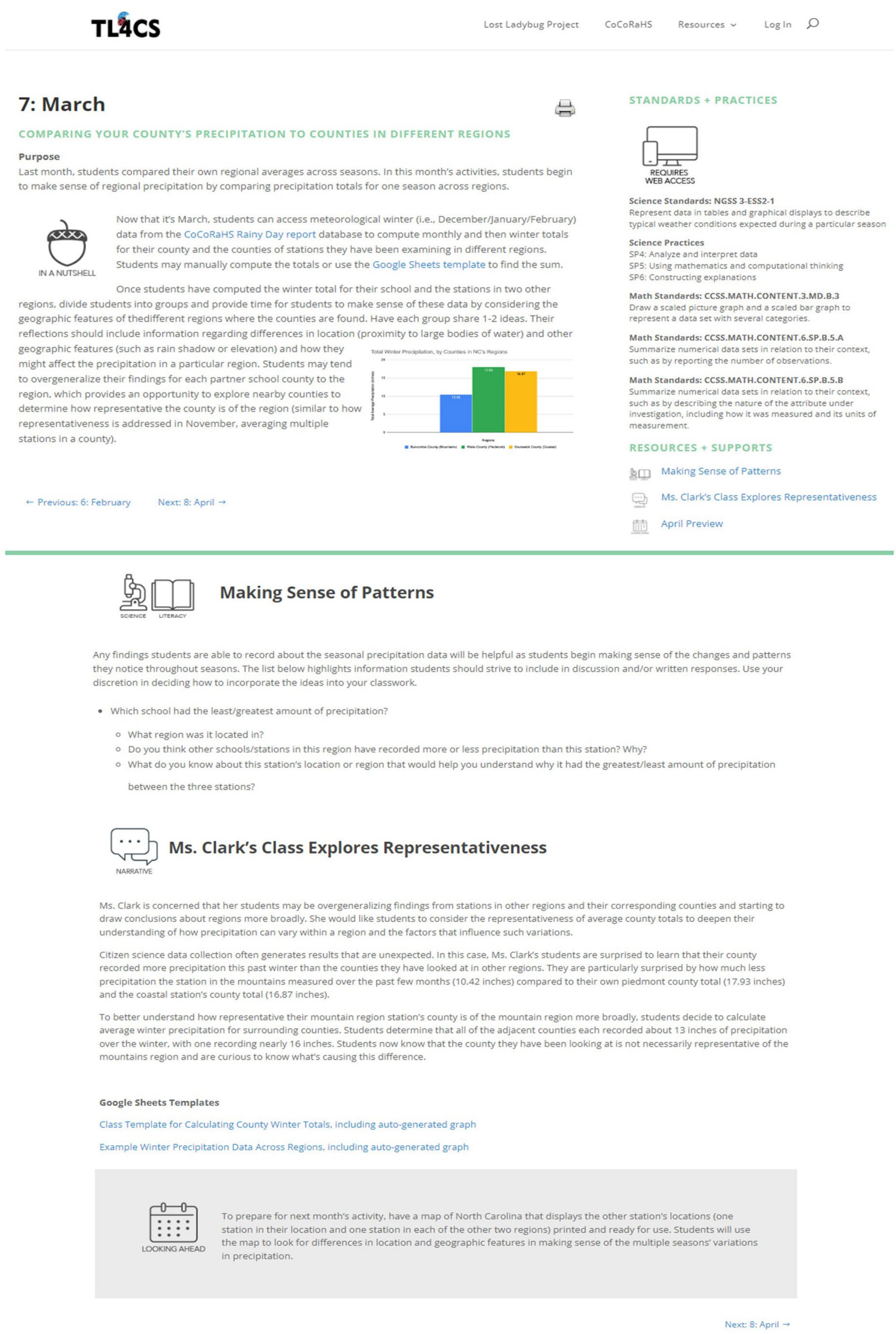
3.1 Participants and settings

We present cases of two teachers, Morgan and Taylor, who were identified because of their similar years of teaching, school contexts, and student populations to document their respective incorporation of SBCS in their classrooms, science instructional decisions, and use of SBCS materials developed for one of the CS projects. Morgan and Taylor both teach fifth grade at different low-performing schools in rural, high-poverty communities. As part of our study's design, Morgan was randomly assigned to receive our support materials for CoCoRaHS, and Taylor had support materials for LLP.

Morgan's school is a rural, Title 1 (an indicator of the high percentage of the students identified as economically disadvantaged) school. At the time of the study, the school had 274 students, with 74% of students eligible for free and reduced lunch (determined by low family income). The school's mathematics and reading performance ratings fell below the state average, and the science performance scores were far below the state's average. Morgan described the school as having "a lot of poverty issues…. being a high-needs school, [it] tends to be [ranked one of] the lowest in the county. We're academically at the bottom, in the bottom three [out of 12 schools in the district] pretty consistently." Morgan is a veteran teacher who chose to join the TL4CS project because "I like science a lot and I enjoy it, but I do not have a deep educational background in science. So that's another reason I'm really excited to do this."

Taylor is also a veteran teacher who teaches at a rural, Title 1 school with 313 students, 52% of whom qualified for free and reduced lunch. Taylor's school's mathematics and reading performance ratings were slightly above the state's average, and science performance scores were below the state average. Taylor's goals for joining the TL4CS project were:

> To learn more myself so that I could be a better teacher, but also to get the students involved in understanding that science impacts them and they can actually participate in real-world science. It's not just something they are reading from a workbook or just a PowerPoint presentation.


TL4CS
Lost Ladybug Project CoCoRaHS Resources Log In

7: March

COMPARING YOUR COUNTY'S PRECIPITATION TO COUNTIES IN DIFFERENT REGIONS

Purpose
Last month, students compared their own regional averages across seasons. In this month's activities, students begin to make sense of regional precipitation by comparing precipitation totals for one season across regions.

IN A NUTSHELL

Now that it's March, students can access meteorological winter (i.e., December/January/February) data from the CoCoRaHS Rainy Day report database to compute monthly and then winter totals for their county and the counties of stations they have been examining in different regions. Students may manually compute the totals or use the Google Sheets template to find the sum.

Once students have computed the winter total for their school and the stations in two other regions, divide students into groups and provide time for students to make sense of these data by considering the geographic features of thedifferent regions where the counties are found. Have each group share 1-2 ideas. Their reflections should include information regarding differences in location (proximity to large bodies of water) and other geographic features (such as rain shadow or elevation) and how they might affect the precipitation in a particular region. Students may tend to overgeneralize their findings for each partner school county to the region, which provides an opportunity to explore nearby counties to determine how representative the county is of the region (similar to how representativeness is addressed in November, averaging multiple stations in a county).

Total Winter Precipitation, by Counties in NC's Regions

← Previous: 6: February   Next: 8: April →

STANDARDS + PRACTICES

REQUIRES WEB ACCESS

Science Standards: NGSS 3-ESS2-1
Represent data in tables and graphical displays to describe typical weather conditions expected during a particular season

Science Practices
SP4: Analyze and interpret data
SP5: Using mathematics and computational thinking
SP6: Constructing explanations

Math Standards: CCSS.MATH.CONTENT.3.MD.B.3
Draw a scaled picture graph and a scaled bar graph to represent a data set with several categories.

Math Standards: CCSS.MATH.CONTENT.6.SP.B.5.A
Summarize numerical data sets in relation to their context, such as by reporting the number of observations.

Math Standards: CCSS.MATH.CONTENT.6.SP.B.5.B
Summarize numerical data sets in relation to their context, such as by describing the nature of the attribute under investigation, including how it was measured and its units of measurement.

RESOURCES + SUPPORTS

Making Sense of Patterns
Ms. Clark's Class Explores Representativeness
April Preview

SCIENCE LITERACY

Making Sense of Patterns

Any findings students are able to record about the seasonal precipitation data will be helpful as students begin making sense of the changes and patterns they notice throughout seasons. The list below highlights information students should strive to include in discussion and/or written responses. Use your discretion in deciding how to incorporate the ideas into your classwork.

- Which school had the least/greatest amount of precipitation?
  - What region was it located in?
  - Do you think other schools/stations in this region have recorded more or less precipitation than this station? Why?
  - What do you know about this station's location or region that would help you understand why it had the greatest/least amount of precipitation between the three stations?

NARRATIVE

Ms. Clark's Class Explores Representativeness

Ms. Clark is concerned that her students may be overgeneralizing findings from stations in other regions and their corresponding counties and starting to draw conclusions about regions more broadly. She would like students to consider the representativeness of average county totals to deepen their understanding of how precipitation can vary within a region and the factors that influence such variations.

Citizen science data collection often generates results that are unexpected. In this case, Ms. Clark's students are surprised to learn that their county recorded more precipitation this past winter than the counties they have looked at in other regions. They are particularly surprised by how much less precipitation the station in the mountains measured over the past few months (10.42 inches) compared to their own piedmont county total (17.93 inches) and the coastal station's county total (16.87 inches).

To better understand how representative their mountain region station's county is of the mountain region more broadly, students decide to calculate average winter precipitation for surrounding counties. Students determine that all of the adjacent counties each recorded about 13 inches of precipitation over the winter, with one recording nearly 16 inches. Students now know that the county they have been looking at is not necessarily representative of the mountains region and are curious to know what's causing this difference.

Google Sheets Templates

Class Template for Calculating County Winter Totals, including auto-generated graph

Example Winter Precipitation Data Across Regions, including auto-generated graph

LOOKING AHEAD

To prepare for next month's activity, have a map of North Carolina that displays the other station's locations (one station in their location and one station in each of the other two regions) printed and ready for use. Students will use the map to look for differences in location and geographic features in making sense of the multiple seasons' variations in precipitation.

Next: 8: April →

FIGURE 3
Sample supports from the TL4CS website.

3.2 Data

The quantitative data sources for each teacher are (1) weekly instructional logs and (2) surveys administered at the beginning and end of the school year. Qualitative data include field notes from six classroom observations, three student focus groups, and eight interviews conducted with each teacher throughout the year. Six of the interviews were post-observation interviews Supplementary materials.

3.2.1 Weekly instructional logs

Participating teachers were asked to complete an online instructional log each week for the duration of the study. The log asked how many days school was in session that week, whether students did anything that week with LLP and CoCoRaHS, and, if so, what they did, including what percentage of students collected and recorded data (i.e., precipitation readings or ladybug sightings). Teachers also responded to questions about their planning and instruction, including which support materials they used, if they used instructional time outside of their scheduled science time for the SBCS activities.

3.2.2 Surveys

At the start of the study, teacher participants completed two surveys (registration and baseline) that asked about their backgrounds, teaching assignments, beliefs about science instruction, the structure and frequency of their science instruction, feelings of preparedness to teach areas of science content and practices, factors that affect their instructional decisions, and how conducive their schoolyard would be for each project. At the end of the school year, teachers completed a survey with many of the same items, allowing us to compare and identify if there were changes in teachers' views about science instruction after incorporating SBCS projects in their classrooms throughout the year.

3.2.3 Observations

All case study teachers were observed six times across the school year to document the incorporation of SBCS projects in their classrooms. For each of their observations, Morgan and Taylor chose a monthly activity from the SBCS project for which they had support materials to guide their lesson. The researcher used an observation template to record key features (e.g., number of students, classroom seating arrangement, schoolyard features, student grouping, student connections with nature, proportion of students engaged, and interdisciplinary connections). The template also included sections for the researcher's field notes that describe the teachers' and students' actions during the lesson, with time point notations throughout. In addition to written descriptions of the activities, the researcher documented the lesson goals (communicated or inferred), interdisciplinary connections, location (inside or outside), and the teachers' use of TL4CS support materials in the lesson. These lesson observations allowed the researcher to learn about the classroom culture and norms, teachers' instructional decisions to align with or adapt the support materials, inclusion and enactment of outdoor instruction, and their interactions with their students.

3.2.4 Interviews

In addition to the observations, each case study teacher was interviewed at the start of the school year, prior to the first observation. This interview asked the teachers about their teaching experiences, their school's policies on science teaching, their typical science instruction in previous years, and any previous experiences with CS. Each of the interviews was conducted over Zoom and recorded. We interviewed teachers after each of the six observations, where we asked them to discuss the observed lesson and respond to questions about the lesson's context (e.g., science lessons prior to the observation) and how the lesson fit into their instruction, their reflections on the features of the support materials and monthly activities, and the teachers' decisions about their use of support materials for that lesson. In each interview, teachers were asked about their comfort teaching both SBCS projects, their use of the CS projects' websites, which of the project support materials they found useful, and features of the support materials they did not use. We also asked teachers to share their impressions of student experiences with SBCS and with the lesson. Near the end of the school year, we asked teachers to reflect on the impact the SBCS projects had on their students, their efforts to position the SBCS activities in their existing science instruction, and how the projects influenced their own teaching and learning.

3.2.5 Student focus groups

Student focus groups took place near the beginning, middle, and end of the school year following a classroom observation. The teachers chose between four and seven different students for each of the three focus group sessions. The focus group sessions lasted approximately 30–45 min. Morgan's students' focus group sessions were conducted at a table in the corner of the school library, and Taylor's were situated in a teacher workroom across the hall from the classroom. The focus group questions asked students to talk about their experiences with both CS projects, things they had learned (cognitive) and how they felt (affective), things that surprised them, parts of the projects they enjoyed or did not enjoy, and their feelings about learning outdoors. Although focus group conversations were not recorded, researchers documented student perspectives using auto-generated transcripts that were used for data analysis.

3.3 Data analysis

Our analysis began by identifying patterns across data sources. We considered initial codes that aligned with the theoretical framework and research questions. Using inductive coding (Hanson et al., 2005; Riger and Sigurvinsdottir, 2016), we identified common codes, organized by themes, to develop a codebook (see Table 1). We coded observation field notes, interview transcripts, and focus group transcripts to document Morgan's and Taylor's incorporation of SBCS in their classrooms and schoolyard and how they navigated their respective school contexts to include SBCS projects in their science instruction.

After discussing initial themes and code meanings, two researchers independently coded common interviews, discussed differences, and agreed on common interpretations of themes. Using qualitative analysis software, Dedoose (2023), the researchers each coded an additional interview, and inter-rater reliability was calculated using Cohen's kappa (Cohen, 1960) at 0.87. Researchers then coded the remaining interviews, student focus groups, and observation field notes.

Additional data included teachers' beginning and end-of-year surveys and teachers' weekly instructional logs. The instructional logs asked teachers to document their activities and classroom decisions

TABLE 1 Sample codebook.

Theme	Codes	Meaning	Sample quote	Source
School context	Administrator support, School demographics, Unit/standard/pacing	How school location, local community, facilities, administrators, etc., affected implementation	"[School] is in a farming community and is a very low SES economic group." (Taylor)	Interview
Teachers' beliefs about students	Student abilities, Student behaviors	Teachers sharing impressions of their students	"They're very interested and they can learn this. Just because they are low in math and reading, does not mean they cannot do science. It just means that I've got to adjust."	Interview
Incorporation in the classroom	TL4CS materials/website, Interdisciplinary connections, Science content/practices, Student experiences with TL4CS	Teachers' instructional decisions and students' experiences with TL4CS	"Students set up their own graphs as Morgan modeled using her computer and displayed to the class. Students who needed assistance brought their computers to Morgan to get help completing theirs."	Observation
Outdoor learning	Teacher view, Students view	TL4CS activities in the schoolyard, Teacher/student views of outdoors as learning space	"There's a lot more to learn outdoors than I thought."	Student focus group

related to the CS project, including their estimates of time students spent on the projects. These weekly estimates were organized by month to display the total monthly time spent on SBCS projects where teachers reported "doing anything" with either project. We used descriptive statistics in SPSS software (IBM Corp, 2023) to analyze these data (i.e., instructional logs and surveys). Individual teacher responses for select items from the surveys are also displayed in tables below.

4 Results

Each of the two case study teachers had over 20 years teaching experience at the time of the study, and both teach at rural schools with similar numbers of students from low-income populations. While neither teacher lived near their school (both commuted approximately 30 min), both shared their views that the rural settings of their schools contributed to the sense of community at the schools. Both also noted some transient populations due to students moving between homes and relatives. Further, each teacher described students in their classes who had been identified with behavioral or academic disabilities. In the initial surveys, Morgan and Taylor reported similar feelings of preparedness to teach science. Using a 4-point scale (not at all prepared, somewhat prepared, fairly well prepared, and very well prepared), both teachers reported feeling "somewhat prepared" to teach Earth/space and physical science, "Fairly well prepared" to teach life science, and "Very well prepared" to teach mathematics.

The similar school contexts and backgrounds of the two case study teachers position the study of Morgan and Taylor's experiences to examine how each navigated their school's context and priorities as they incorporated SBCS in their classrooms.

4.1 Morgan

At the time of the study, Morgan had been an elementary school teacher for 26 years and planned to retire in 2 years. In college, Morgan majored in history, then followed an alternative path to earn a teaching license. When asked about school district opportunities for professional development in science, Morgan said, "There is never any science offered," and went on to describe personal efforts to learn more about science. One opportunity Morgan found was a mathematics professor from a local university who, because of his interest in weather and education, developed videos that he designed to help teachers learn about weather. Prior to the study, Morgan had not participated in any CS projects and reported low to moderate confidence incorporating CS in science instruction.

4.1.1 School context

We asked teachers to reflect on how their school context influenced their instructional decisions to include SBCS in their classroom and outdoors. In an initial registration survey, teachers rated school context factors as either: Inhibiting, Neutral, or Promoting effective science instruction. Morgan indicated that their principal's support of science instruction promotes effective science instruction in the school. In an early interview, Morgan illustrated this by explaining that the principal himself had helped install the CoCoRaHS outdoor rain gauge in the schoolyard. In a survey at the beginning of the school year, Morgan rated the schoolyard as "Very conducive" for placing a CoCoRaHS rain gauge and having students read it without direct adult supervision because it was visible from the classroom window, and Morgan selected "somewhat conducive" for the schoolyard's potential for students to collect ladybugs with adult supervision. Morgan rated the time for science instruction as "Sufficient," but time to plan science instruction effectively as "Insufficient." In an early interview, Morgan described personal goals to learn more about science as influential in their decision to participate in the TL4CS project.

Another factor that motivated this decision was a lack of science curriculum materials. Morgan explained that, while the state provides science standards and there are district pacing guides, the school district does not provide science curriculum materials "There's no science textbook… 'Teachers Pay Teachers' [an online marketplace for teacher-created lesson plans] and I have become good friends." Prior to this study, Morgan described trying to find lesson plans online that aligned with the state's science standards. Morgan described an unstructured approach to science teaching and explained the decision process for finding lesson plans:

> Some vocabulary, some video links. It would have some experiments, it would have some data collection, and then it would have some summative activities. And then at the end, I would give them a test using science questions [from the state test] to see where we were and then go back and reteach where we had missed areas.

Morgan emphasized how the state-administered fifth-grade science test influenced teachers' planning for science instruction. In an interview, Morgan explained other teachers' opinions of the science test as "just a reading test…. If you'll just teach them the vocabulary, they'll be fine." Morgan elaborated, "I do not think that's how science works."

Morgan explained joining TL4CS because "I wanted something that was exciting, where I was learning and I was not having to do it by myself," and no longer wanting to "wing it" with science instruction. As the year progressed, Morgan recognized how using the TL4CS support materials impacted their science content and instructional practices saying, "The most important piece here was it gave me permission, quite frankly because I was part of this study, to walk away from teaching to the test."

4.1.2 Beliefs about students

Morgan described the class of 21 students as an "even mix of boys and girls," three academically gifted students, two students identified as English language learners, and nine students with Individual Education Plans in reading, indicating students spent time out of the classroom for additional reading support. Five students were identified with ADHD, two with oppositional defiant behavior, and two students were receiving treatment for anxiety disorders, "so a lot of mental health disabilities," as Morgan put it. Despite these potential obstacles to learning, Morgan expressed beliefs that, with adaptations, the students were capable of learning the material:

> I just have to present it in a different format. We do more drawing, we do more foldables, we do more concrete that's not writing- or reading-based… to make sure that they can do the activity and be successful…. They've not really had much science coming in [to my class], and they are very interested and they can learn this. Just because they are low in math and reading does not mean they cannot do science. It just means that I've got to adjust.

4.1.3 Incorporation in the classroom

On the weekly instructional log, Morgan reported student involvement with one of the SBCS projects almost every week of the school year. Figure 4, which displays the time spent on both projects by month, indicates that Morgan reported involvement with CoCoRaHS (the CS project with TL4CS support materials) for greater amounts of time and more frequently than LLP (for which Morgan did not have support materials). Morgan's instructional log data document student activity with CoCoRaHS (e.g., checking the rain gauge, entering data, or doing class activities) for 31 weeks of the school year, and in an interview, Morgan described CoCoRaHS as a "routine" part of the class.

Although not included in the support materials, Morgan's class set up a bulletin board in the hallway where students recorded their CoCoRaHS data (daily precipitation amounts) along with other weather data for other classes in the school to see. Morgan felt that sharing data on the bulletin board contributed to students moving beyond data collection.

> It really helped that I had the bulletin board set up where we did weather data every day. So not just collecting the precipitation amounts, but the daily temperature, creating the graph out in the hallway. "What's the season, how does it feel?"

When students were asked in a focus group about what they had learned from the SBCS projects, one student said, "Besides reading the rain gauge, we study where the measurements are going, how fronts go from west to east." Another student described learning "about how precipitation works - the water cycle."

In contrast to 31 weeks of time spent on CoCoRaHS, the SBCS project with support materials provided, Morgan reported student activity time with LLP (e.g., searching for ladybugs, entering data, or doing class activities) for 4 weeks of the school year. In the end-of-year interview, Morgan included activities for LLP during the scheduled ecosystem unit:

> I did not do anything with it other than sort of talk about it a little bit until the very end of the year. And then we did it every day for 2 weeks. And that was just hunting for ladybugs.

Morgan explained that, without having TL4CS support materials for LLP, the LLP activities consisted only of data collection - students searching for ladybugs - without any sense making of the data. Morgan shared that having support materials for the CoCoRaHS facilitated the inclusion of SBCS. In addition, Morgan found the accessibility of the two CS project websites (www.cocorahs.org and www.lostladybug.org) differed, and options on the CoCoRaHS website for visualizing the precipitation data they submitted were engaging for both the students and Morgan too. Morgan said students' experience with the two project websites affected their overall enthusiasm for each project. As Morgan described:

> They started looking for insects a lot, so that was really positive. But their enthusiasm about the website, not so much. Whereas [the] CoCoRaHS website had a lot of things… that I had taught them because we had the [TL4CS] lessons. They could go in and they could see our weather station. They could see the whole United States. They could go in and look at data.

Morgan's interviews revealed instructional decisions that were tailored to meet student needs. After reviewing activities in each month's support materials, Morgan recognized areas where students needed extra help and, when necessary, Morgan adapted the TL4CS support materials to position students for success. For example, in one lesson, Morgan recognized gaps in students' knowledge about the geography of the state, content that should have been taught in 4th grade. To address these gaps, Morgan started the lesson with an overview of the state's geographic

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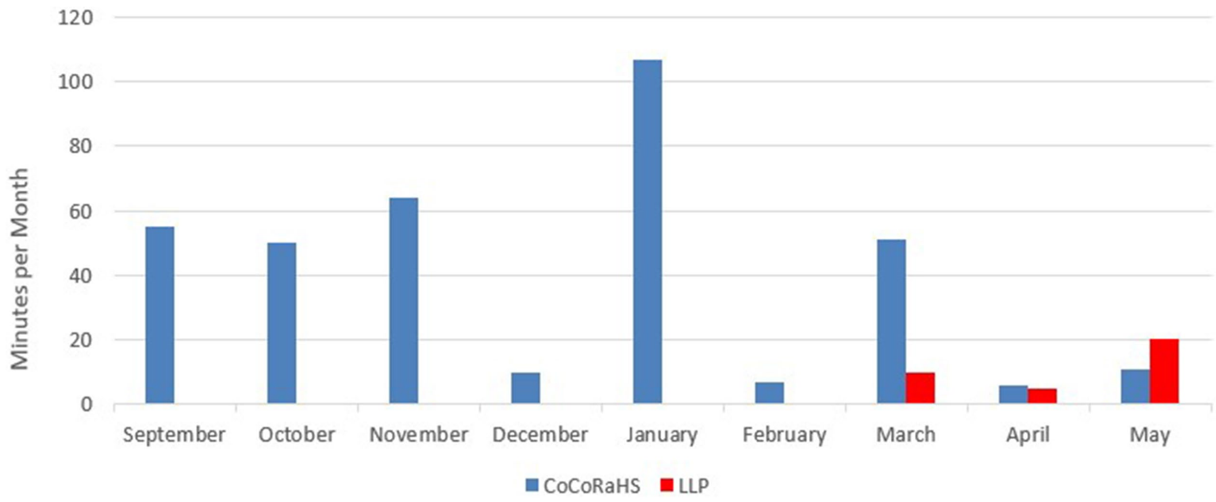

FIGURE 4
Morgan's total monthly time on SBCS projects (self-reported on weekly logs).

features, including a mini-lesson on map skills. Interestingly, Morgan chose to use maps from the CoCoRaHS website to reinforce students' knowledge of the state's geography. Morgan explained, "I do not think they got a lot [of 4th grade social studies instruction] last year, so we have really been talking about physical geography." Similarly, Morgan recognized gaps in students' mathematics knowledge saying, "I realized the kids were not going to be as independent as I might have hoped for them to be able to create a graph, so there were a lot of skill-based things that I needed to go over." In another example of scaffolding students' mathematics skills, in a monthly activity that required students to graph precipitation data, Morgan first modeled for students how to set up and label a graph and then gave step-by-step instructions for the students as they created their own graphs.

Still another example of Morgan's tailoring lessons to support student learning was discussed during an interview about planning for a lesson that required students using spreadsheets. Morgan was initially skeptical about students' abilities to use spreadsheets. Morgan adapted the activity to scaffolded student learning by first modeling for students how to find their school's precipitation data on the CoCoRaHS website, then showed students how to cut and paste their rain gauge data into a spreadsheet template that was provided in the TL4CS support materials. As students watched Morgan's example, they replicated it on their own computers. With this scaffolding and practice, most students eventually were able to complete this task independently. Morgan was proud of students' success and explained sharing this excitement with the principal and inviting him to observe the students' work. "I actually went and got my principal the next day and I said, I want you to come see what these kids are able to do now… and he said, 'Whoa, look at 'em go.'" In a focus group, one student confirmed how reading the rain gauge all year helped them to learn about "the decimals to where we understand how much it is," and another student said, "We measure the precipitation by hundredths."

4.1.4 Outdoors

In a survey that asked questions about instructional practices prior to TL4CS, Morgan reported "rarely" taking students outside for science instruction. Nonetheless, field notes from an observation early in the school year documented Morgan taking the whole class outside to introduce students to scientific observations of weather. Morgan showed the students where the rain gauge was mounted and then took them on a weather walk to "ask them what it [weather] felt like on their skin. And so lots of observations of using their senses." In the first focus group, students talked about those outdoor experiences. One student said, "I used to hate it (outdoors) and I love it now." Another student explained, "There's a lot more to learn outdoors than I thought." As the year progressed, two to three different students read the rain gauge each day, and those students recorded the daily observations on the hallway bulletin board. In the second focus group, one student compared learning indoors and outside saying, "I feel more thoughtful about things in the outdoors" and another explained that when outdoors, "I observe more."

4.1.5 Summary

Morgan chose to participate in TL4CS to learn more about science and science instruction, and these data offer evidence of both students' and Morgan's learning. Morgan's relationship with the *curriculum* might be described as a "learner/modifier." Observations and interview data reveal Morgan devoting significant time to review both the TL4CS support materials and the CoCoRaHS website. Importantly, Morgan acknowledged *contextual* factors - the school's low-income community and label as a low-performing school by the state. Despite these obstacles, Morgan embraced the materials, adapted and supplemented activities to meet student needs, and demonstrated high expectations for student success. Morgan's enactment of the curriculum (e.g., planning, adapting to student needs) reveals a student-focused teacher. Interestingly, while initial observations document Morgan's presentation of the monthly activities as written, in an interview near the middle of the school year, Morgan described realizing that the support materials were intentionally designed to be flexible for teachers to adapt rather than rigidly followed. Morgan was excited about having "permission" to make professional decisions about adapting lessons to meet students' needs, documenting Morgan's developing relationship with the support materials.

4.2 Taylor

Prior to the study, Taylor had taught for 20 years, mostly as a 6th grade mathematics and science teacher. Taylor had taught 4th grade for four of those years, and at the time of the study, Taylor had taught 5th grade at this school for 2 years, teaching only science. Taylor explained that the new principal was transferred to this school and tasked with improving the school's test scores, so "my position was changed so that there was a dedicated teacher for [tested] 5th grade science." Like Morgan, Taylor did not major in science or education in college. Upon graduation from college, Taylor followed an alternative path to earn a teaching license. At the time of the study, Taylor had not participated in any science-focused professional development for over 10 years and reported limited opportunities for professional development in science. Prior to the study, Taylor had not participated in CS projects and reported low confidence levels for incorporating CS with science instruction.

4.2.1 School context

Taylor's school is in an economically depressed community, having lost its former industry-based income sources. Taylor explained the school's low performance:

> I do not mind telling you because it's a matter of public record that our school scored a 'D' on the state report card for this past year. So overall, that kind of gives you an idea of where they are academically. We also have a lot of students, they are transient, because they are in foster care.

Despite this, Taylor described the school community as strong, but Taylor also found it hard to connect with students. "Sometimes it's hard to reach them because they do not want to build relationships, even with other students."

In a survey that teachers completed early in the school year, they were asked about factors that affect their science instruction. The choices were "Inhibits effective instruction," "Neutral," or "Promotes effective instruction." Taylor rated the principal's support as "Neutral," and this was illustrated when 4 months into the school year, the principal told the researcher that she had not yet seen signs of students' improvement on quarterly benchmark assessments administered district wide. The principal told the researcher that she hoped to see growth, illustrating the principal's and district's focus on test scores and accountability. Taylor explained "There's so much expectation of meeting goals for science… you are constantly beating them with the vocabulary and all of the practice tests and things like that."

In the same survey, Taylor selected "Inhibits effective instruction" when asked about time for science planning, instruction, or time to participate in professional development. Taylor also identified textbook/module selection policies as inhibiting effective science instruction. In an early interview, Taylor said, "Any materials that I had or used, I had to pull off the internet or pay for myself." Taylor went on to say, "I would definitely do a lot more if I had the budget, and if I had the time, I would definitely do a lot more interaction with the students and have them actually doing science."

In evaluating the school's outdoor context, Taylor rated the schoolyard as "Very conducive" for students to read the rain gauge for the CoCoRaHS project without adult supervision and searching for ladybugs for LLP, providing there was adult supervision. However, in an interview at the beginning of the study, Taylor said that it was "hard logistically to get the students outside, to do any kind of science."

4.2.2 Beliefs about students

At the beginning of the study, Taylor described the class of 20 that included three students identified as English language learners, and three students as having learning disabilities. When asked about students, Taylor said, "I'm not making excuses…. I would not say they are bad kids, they are not defiant, they are just not mature, just not very well socialized…. It can be, that can be a challenge finding a way to reach the kids and getting them excited about learning." Throughout the school year, Taylor expressed challenges related to student learning.

4.2.3 Incorporation in the classroom

Taylor's instructional log data documented students doing activities related to LLP (the project for which Taylor had support materials) for 16 weeks of the school year (less than half the school year) and 0 weeks of activities related to CoCoRaHS. The log data were also used to calculate the time spent on both projects by month (see Figure 5). End-of-year survey data document that Taylor's confidence in implementing LLP with students increased, while confidence implementing CoCoRaHS project remained low.

In visits to Taylor's classroom, we observed what might be best described as traditional or direct instruction. During a 50-min lesson observed in November, Taylor started with a lecture on producers, consumers, and decomposers with a few mentions of ladybugs, and Taylor took the class outside for the final 8 min to search for ladybugs. Field notes document that Taylor began each monthly TL4CS activity showing a slide displaying state science standards and objectives, then students were asked to respond to practice multiple choice test questions from the state's science assessments. Taylor often showed short video clips to communicate science content, and observation field notes show the majority of time that Taylor devoted to the CS project was students watching videos or passively listening to Taylor's instruction. Interestingly, when asked in a focus group about the SBCS projects, one student expressed an appreciation for the outdoor time. "I do not really like bugs a lot, but I like this project because I like doing, and everyone is involved, and I like to do projects." Despite student enthusiasm, Taylor explained that there was limited time for the SBCS projects, including outdoor data collection needed for LLP, because of accountability pressures to prepare students for standardized tests in science.

Like Morgan, Taylor's perceptions of students influenced instructional decisions, but unlike Morgan, Taylor expressed limited confidence in student abilities. "We give the background necessary, but then encourage the students to practice it… every year it seems like the attention span is shorter and shorter." This lack of confidence influenced Taylor's decisions to skip parts of the monthly activities that Taylor felt were too difficult for the students, saying, "I pick and choose what I can do based on the amount of time I have and the needs of my students and the abilities of my students." In explaining the decision to skip a mapping activity, Taylor said that students "really had not spent a lot of time with coordinates and looking at coordinates. And I knew I would be spending a lot of my time trying to teach." As the year progressed, Taylor attempted to include more features of the TL4CS monthly activities, sharing, "I was surprised at how well they were able to take the information from the reading… understand the content, and look at the perspectives. I was concerned the readings were a bit over their heads."

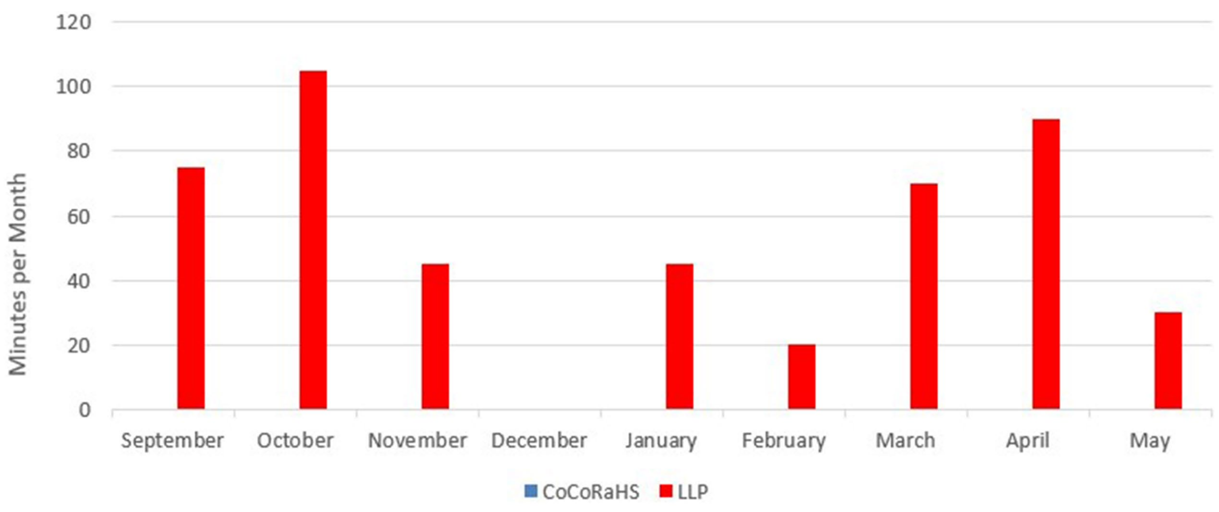

FIGURE 5
Taylor's total monthly time on SBCS projects (self-reported on weekly logs).

4.2.4 Outdoors

Taylor reported having rarely taken students outside for science instruction prior to the study, and as the year went on, Taylor continued to express hesitation about taking students outdoors. In Taylor's words, "Even just keeping them somewhat corralled can be challenging… part of it's enthusiasm, and part is they just really struggle with basic adherence to rules that you lay down." Students searched for ladybugs in some of the observed lessons, and observation data documented student outdoor time lasting 10 or fewer minutes. Students confirmed this limited outdoor time in focus groups.

Focus group data suggest that the time spent outdoors, although limited, was impactful for students. One student described learning outdoors, "I am more observant. I pay more attention." Another student appreciated outdoor time saying, "We get to move and talk with each other when we are outside." Promisingly, in an end-of-year interview, while Taylor acknowledged being the kind of teacher where "desks are lined up and everything has its place," Taylor shared learning that students "do not have to just be behind the desk" and expressed future intentions for "getting them outdoors more."

4.2.5 Summary

Taylor chose to participate in the project to "be a better teacher" and to offer students opportunities to participate in "real world science." While the data presented here demonstrate Taylor's inclination toward teacher-led, or direct instruction, there is evidence of engagement by student engagement through the incorporation of SBCS. Students searched for ladybugs outdoors and tried to identify ladybug species from photos, but field notes indicated that "the students love going outdoors, but it seems that does not happen often, and there are no discussions related to the particular schoolyard ecosystem (vegetation or features)." Most lessons seemed to consist of vocabulary review and test preparation, and students did not participate in data analysis or share data with the science community." Taylor's relationship with the curriculum can be described as a "selective user," with Taylor's decisions about what to include often driven by skepticism about students' abilities and other instructional priorities. Taylor frequently mentioned administrative pressure to prepare students for science assessments as a contextual influence, viewing science activities that were not directly related to the tested concepts and vocabulary as competing for instructional time.

5 Discussion

The overarching goal of our research is to study how CS projects and accompanying support materials can enhance teachers' science instruction in elementary classrooms. Despite the history of limited science instruction in elementary grades (Appleton, 2013; Plumley, 2019), in recent decades, researchers have identified young children's capacity for understanding the natural world and engaging in the science practices (National Academies of Sciences, Engineering, and Medicine, 2022; National Research Council, 2007, 2012; Roth, 2014). Because science instruction in early years can help build students' capacity for understanding science, elementary school years are a critical time for nurturing students' interest and engagement in science (Murphy et al., 2007; Sorge, 2007). Researchers have also identified inequities in elementary school science teaching that have resulted in achievement gaps in racial, gender, ethnic, and socioeconomic groups, including in rural settings (Barton and Tan, 2009; Lee et al., 2006; Roth, 2014). Data from this study confirm constraints to science teaching in rural classrooms that include limited materials, curriculum, and opportunities for professional development (Zinger et al., 2020).

The cases discussed here are situated in a larger study designed to identify how CS projects that include educative support materials can promote elementary school teachers' and students' learning of science content and enhance teachers' science pedagogy. Importantly, these SBCS materials are designed to help teachers learn to engage all students in authentic data collection and sense-making experiences in science (Berndt and Nitz, 2023), offering potential to close achievement gaps in elementary student populations (Wu et al., 2021). Our focus on two veteran elementary school teachers, Morgan and Taylor, is framed in Remillard's (2005) theory (Figure 1) that identifies factors that influence enacted instruction - teachers, students, context, and curriculum - and the commonalities of Morgan and Taylor's student populations, school contexts, and SBCS curriculum help us focus on the important role of the teacher.

Both teachers shared backgrounds of alternative teacher licensure; years of teaching experience; and teaching in small rural schools of similar size, student populations, and low-income status. These teachers identified similar goals for participating in the TL4CS research project to support their own and their students' learning of science. Importantly, these two veteran teachers chose to participate in the study that they understood would involve incorporating new practices and routines into their instruction.

Despite these commonalities, our findings identified the teachers' contrasting approaches to incorporating SBCS projects in their classrooms and schoolyards. Instructional log, observation, and interview data document Morgan's commitment to using the project's SBCS support materials. Despite reporting limited time for planning science, Morgan took up the materials enthusiastically and encouraged students' participation in data collection and analysis. In contrast, despite the TL4CS support materials' alignment with the state's science standards, Taylor found it hard to make time for SBCS. Taylor's teacher-centered instruction and school pressure for high test scores seemed to encourage a view that science instruction is a transfer of science knowledge (Shaw, 2016), and this view may explain observation data that documented Taylor's decisions to abbreviate student opportunities with the monthly activities.

The TL4CS support materials were intentionally designed to allow for teacher autonomy in decisions in using the materials. In recognizing this flexibility, Morgan expressed appreciation and described how this contrasted with various initiatives introduced through the years that required teachers to use scripted, teacher-centered curricula. Such expectations have been found to be especially common in high-poverty areas (Ede, 2006). In addition, because neither Morgan's nor Taylor's schools provided them with lesson plans for science, both said they searched for science lesson plans online. Morgan described purchasing science lessons from Teachers Pay Teachers, but a review of 31 lessons from this source found that, despite claims of alignment with NGSS, none of the lessons included all of the key features of NGSS (Summers, 2024). While both teachers adapted the TL4CS support materials to meet student needs, their different perceptions of student potential are shown by their decisions. Taylor's adaptations limited or omitted student experiences with the monthly activities. In LLP support materials, students are asked to record locations where ladybugs were found on a map of the schoolyard and connect with features of the habitat. Taylor omitted students identifying locations on a map and explained that students had little experience with map coordinates. In contrast, Morgan's adaptation decisions were designed to scaffold student learning. While Morgan, too, recognized gaps in students' map skills, Morgan's response was to review mapping skills and coordinates with students and model map use for students. The teachers' adaptations of the TL4CS materials reveal differences in beliefs about their students. Morgan's belief about student potential and Taylor's belief that activities were too complex for students exemplify Roth's (2014) notion that a teacher's perceptions of student abilities can serve to widen gaps in student learning. These data highlight differences in teachers' relationships with support materials, instructional planning and enactment, and potential for teacher and student engagement with SBCS.

Despite differences in approaches to SBCS, Morgan and Taylor had similar experiences with structuring outdoor opportunities for their students. Both teachers recognized their students' enthusiasm for spending time in the schoolyard. Student focus group data documented student descriptions of cognitive and affective benefits of spending time outdoors, sharing feelings of focused thinking and appreciation of nature (Ayotte-Beaudet et al., 2023; Rios and Brewer, 2014). Despite having support materials that provided opportunities for outdoor learning, both Morgan and Taylor reported that finding time to take students outdoors inhibited their ability to capitalize on learning opportunities in the schoolyard (Patchen et al., 2024). Promisingly, both teachers expressed intentions to include more outdoor learning experiences for future students.

As the year progressed, both teachers reported increased confidence in teaching science and incorporating CS projects for which they had support materials, indicating the potential benefits of SBCS projects for both student and teacher learning (Arias et al., 2016; Davis et al., 2014; Davis et al., 2017). Taylor explained learning how to teach students about point of view from a TL4CS activity that provided readings on positive and negative perspectives on ladybugs. Morgan expressed confidence in learning about using spreadsheets for organizing data and how to incorporate the activities in science instruction.

While data from this study document the complexities of introducing SBCS in elementary schools, they also reveal the potential for SBCS to provide young students opportunities for authentic data collection and analysis and support both student and teacher learning. Amongst the important factors to consider when designing SBCS - teachers, curriculum, context, and students - we highlight the teacher and related factors that impact a teacher's implementation of SBCS. Thompson et al. (2013) explain that implementing new curriculum relies on teachers' expertise and confidence. Bopardikar and colleagues (2023) recommend CS curriculum designers use a context-based learning approach centered on students' lives and promote understanding of science content, and SBCS curriculum developers should also include teacher voices in the design process (Carrier et al., 2024). With activities that engage teachers and students in authentic science inquiry, SBCS projects can help students and teachers feel part of a community with scientists and, importantly, build science knowledge for teachers and students.

6 Conclusion

SBCS has the potential to engage students in authentic data collection and sensemaking, and the findings in this study demonstrate this potential and reveal challenges that teachers encounter to include SBCS in classrooms. In this study, we learned that SBCS materials can enhance teachers' content knowledge and instruction (Arias et al., 2016; Davis et al., 2017), and our findings highlight how factors in schools such as the context and students contribute to benefits and challenges for teachers to include SBCS in their science instruction. These and other teachers' science instruction would benefit from schools that prioritize science, including ongoing professional development for science (Zinger et al., 2020). Importantly, developing support materials for SBCS can support both teacher and student learning, and introducing students to CS offers opportunities that connect science to students' lives (Appleton, 2013; National Research Council, 2012). In addition, these experiences can help students learn science practices of data collection and the frequently neglected data analysis and sense-making. The two teachers in this study illustrate both the strengths and challenges teachers face and can inform CS project designers' efforts to support SBCS (Bopardikar et al., 2023). Chief among these are administrator support, school pressure for accountability, and teacher beliefs about their students' competence.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

The studies involving humans were approved by Horizon Research, Inc. Chapel Hill, NC. The studies were conducted in accordance with the local legislation and institutional requirements. The participants provided their written informed consent to participate in this study.

Author contributions

SC: Conceptualization, Formal analysis, Funding acquisition, Investigation, Methodology, Supervision, Writing – original draft, Writing – review & editing. DS: Data curation, Formal analysis, Methodology, Validation, Writing – original draft, Writing – review & editing. MH: Methodology, Project administration, Resources, Writing – original draft, Writing – review & editing. PS: Formal analysis, Funding acquisition, Project administration, Resources, Supervision, Writing – original draft, Writing – review & editing. AB: Resources, Visualization, Writing – review & editing. LC: Data curation, Formal analysis, Software, Validation, Writing – review & editing.

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Conflict of interest

DS, MH, PS, AB, and LC were employed by Horizon Research, Inc.

The remaining author declares that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

Supplementary material

The Supplementary material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/feduc.2024.1470070/full#supplementary-material

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