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Elementary teachers' use of educative support materials for citizen science projects: affordances, obstacles, and impacts

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ABSTRACT

Formidable obstacles constrain elementary teachers' efforts to provide science instruction that creates opportunities for students to engage with science. These include limited instructional time, inadequate access to high-quality instructional materials and professional learning, and teachers' self-efficacy. Citizen science, or community science, supports teachers by offering ways to engage students in science and in collecting and interpreting data connected to students' lives. While citizen science projects emphasise gathering accurate data fundamental for scientific success, they may not align with teacher needs. Using Remillard's model of teachers' participatory relationship with curriculum materials, we studied how project-specific educative supports could facilitate teachers' use of citizen science projects in formal settings. We selected two projects and developed educative support materials. We present data from 52 teachers in a randomised controlled trial investigating (1) how teachers used the materials and (2) how the materials impacted use. Access to project-specific educative supports has a large positive effect on teachers' and students' use, and teachers value some supports more than others. We situate our work in research on teachers' relationship with instructional materials, design of educative curriculum materials, and school-based citizen science. We discuss the implications for project designers, science education researchers, and science teacher educators.

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Introduction

The Next Generation Science Standards (NGSS; NGSS Lead States, 2013) call for a fundamental shift in how students experience science in formal education settings, advocating for experiences that interweave disciplinary core ideas, science practices, and crosscutting concepts (what the NGSS refers to as 3-dimensional instruction). These calls for enriching science education exist globally and connect with school policies

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(Duschl et al., 2021). However, the frequency and depth of science instruction in elementary schools pales in comparison to mathematics and reading instruction (Plumley, 2019). In the US, science averages about 20 min per day versus 90 min for English language arts and 60 min for mathematics. Elementary school teachers describe barriers to providing strong science experiences for students, including lack of time and support for science instruction, and only one-third see themselves as very well prepared to teach science (Plumley, 2019), and this pattern extends in many other countries (Bansal & Ramnarain, 2021; Haug & Mork, 2021). Continuous professional learning opportunities are critical for teachers to support their students' science learning (Wilson, 2013), but over 40% of elementary teachers report participating in no science-related professional learning in the preceding three years (Banilower et al., 2018). Teachers also report limited access to high-quality curriculum and resources to support student science learning and engagement (National Academies of Sciences, Engineering, and Medicine, 2022; Penuel & Reiser, 2018). The instructional materials elementary teachers use most frequently are those they create themselves (Doan et al., 2023). All these data suggest that the vision of the NGSS and science education reforms have not been fully realised (Duschl et al., 2021; Smith, 2020).

Citizen science engages individuals who are not professional scientists in scientific endeavours, typically in collaboration with or supervised by professional scientists. Often, citizen science projects invite many individuals to collect data, expanding the capacity of professional scientists and making research possible that would not be otherwise. While some question the quality of data collected by non-professionals, Bonney et al. (2014) found that 'with appropriate protocols, training, and oversight, volunteers can collect data of quality equal to those collected by experts' (p. 1496). Thousands of citizen science projects exist across a broad range of science disciplines, and most of these can be described as contributory, meaning participation is limited to collecting and reporting data (Bonney et al., 2009). However, other types of citizen science projects expand the involvement of participants. In collaborative projects, participants often help refine the study design and disseminate results, and in co-created projects, participants and professional scientists jointly design the project around a problem of mutual interest (Bonney et al., 2009).

School-based citizen science (SBCS) shares many affordances with citizen science in other contexts, but engaging teachers and their students in citizen science has the potential to provide science learning opportunities in the context of project-based science inquiries (Aristeidou et al., 2023; Atias et al., 2023; National Research Council, 2012). For our study, we focused exclusively on contributory projects for two reasons. First, a wide variety of contributory projects already exist and are easily accessible to teachers. SciStarter, a clearinghouse of citizen science projects, lists over 1,700. Second, contributory projects offer comparatively easy entry into citizen science. Teachers and their students can 'plug into' an existing project with relatively little effort and with limited experience in science. This affordance comes with a potential limitation: although teachers and students can easily contribute data, opportunities to participate in knowledge building can be constrained. Contributory and co-created projects offer more in-depth involvement (and potential benefits) but can also require more time commitment.

In the context of contributory projects, we argue that at its best, SBCS moves beyond students only collecting and reporting data to providing teachers with opportunities to

help students use science practices (NGSS Lead States, 2013) to make sense of those data (and data collected by others) to construct understanding of science concepts. When citizen science projects connect with existing education standards for science and other disciplines, they can be woven into lessons rather than added on as separate instruction (Lucky et al., 2014). SBCS can also increase students' engagement in science and in their community (Condon & Wichowsky, 2018), and it can build STEM content knowledge and skills (Kermish-Allen et al., 2019). Tsybulsky and Tal (2025) outline many of the affordances of SBCS. For example, when students engage directly with scientific phenomena through CS projects, they are immersed in authentic scientific research and have the opportunities to collect, analyse, and interpret real data. Further, participation in CS projects strengthens students' content knowledge by situating learning in real-world contexts and often encourages students to make connections to local ecosystems.

SBCS can affect affective outcomes as well. Araújo et al. (2021) found that student participation in SBCS projects positively impacted their attitudes about science. Similarly, Atias et al. (2023) found that students and teachers saw themselves as contributors to scientific research when using CS projects in school, highlighting the importance of the relationship between schools and scientific research. SBCS has the potential to increase teachers' motivation and students' interest when projects are closely connected to the curriculum, and some studies report students' strengthened science identities when participating in CS projects (Tsybulsky & Tal, 2025). Harvey et al. (2020) examined a biodiversity programme for primary school students in their schoolyard and concluded that even 1 h a week spent outdoors positively impacts students' wellbeing and mood. Finally, SBCS has the potential to address previously identified inequities in citizen science projects, which tend to involve individuals who are disproportionately well educated, White, upper to middle class, and older (National Academies of Sciences, Engineering, and Medicine, 2018).

Although many citizen science projects connect students with authentic data collection, relatively few offer substantial guidance for teachers. Fewer than a quarter of the active projects listed on SciStarter.org include accompanying classroom materials, and those materials vary widely. Often, they focus on data collection protocols, not what students can do with the data. They typically do not provide teachers with guidance that would help them use these projects to provide the kinds of learning opportunities envisioned in the *Framework for K-12 Science Education* (National Research Council, 2012) and global science curricula (such as, British Columbia Ministry of Education, 2016; NGSS Lead States, 2013; South Africa Department of Basic Education, 2011; Thailand Institute for the Promotion of Teaching Science and Technology, 2008). One way to support teachers' use of citizen science is to develop accompanying educative support materials. Such materials are 'designed to promote teacher learning as well as student learning' (Davis et al., 2014, p. 25) and include supports that help teachers acquire content and pedagogical content knowledge to inform their instruction (Arias et al., 2016; Davis et al., 2017). These supports include conceptual storylines, content background for teachers, content-specific pedagogical guidance, and suggestions for assessments. Davis et al. (2014) outline a design process for such materials that begins with analysing existing curriculum materials using five lenses (science content, scientific practices, literacy practices, participation structures, and assessment). Educative features (i.e. text and graphics) are then developed and embedded into curriculum materials. Such features can save teachers considerable time and effort. By embedding the supports in

instructional materials, educative supports also address the need for subject-specific professional learning.

As teachers plan instruction, they translate *written* curriculum to *planned* curriculum, and ultimately to *enacted* curriculum (Remillard, 2005). Educative curriculum materials can facilitate each of these translations, supporting teachers' planning and enactment of science instruction. For this reason, our team has used the term 'supports' or 'support materials' in referring to the educative curriculum materials we developed for two existing citizen science projects. Design principles for educative curriculum materials (Davis et al., 2017) guided our development work. Two particularly influential ones are:

- Design Principle 1: Teachers will adapt curriculum materials. ... Therefore, educative features should provide suggestions for adaptations of lessons that would take different amounts of time and meet a range of students' needs while still meeting the intent of the reforms embedded in the curriculum materials.
- Design Principle 4: Different teachers will need and take up different kinds of educative features (in terms of substance and form). ... Therefore, designers should develop a constellation of educative features that have the potential to meet these various needs. Designers should also help teachers recognise how the recommendations differ from their current practice, in part through emphasising the rationales for the recommendations (Davis et al., 2017, p. 301).

Theoretical framework

Our study is situated at the intersection of formal education in elementary grades and citizen science, examining how the use of educative curriculum materials (ECMs) optimises the benefits of citizen science for teachers and students. Following an extensive review of the literature on teachers' use of mathematics curricula, Remillard (2005) proposed a model asserting that teachers interact with curriculum materials in a participatory relationship. The model distinguishes between the written curriculum, planned curriculum, and enacted curriculum (what transpires in the classroom). Four forces – the teacher, the curriculum, the students, and the context – as well as interactions among them shape the enacted curriculum. Both the teacher and the curriculum have features that shape the relationship. The teacher brings their own attitudes, beliefs, knowledge, and skills. The curriculum is characterised by particular representations of concepts, representations of tasks, and instructional structures, among others. The teacher clearly changes the curriculum deciding how to adapt it for their students, but the curriculum also changes the teacher. This last point is critical for understanding the role played by educative curriculum materials. When a curriculum includes educative features, they can support teachers in purposefully adapting and using the curriculum (Davis & Krajcik, 2005).

Our stance regarding SBCS reflects Remillard's work (Smith et al., 2025). Teachers have a relationship with a citizen science project, which several factors mediate. Foremost among these are the project itself, any accompanying support materials for teachers, the teacher, the students, and the context. The mediated relationship shapes how students engage with the project and what they learn. Teachers' own backgrounds shape the decisions they make about using the citizen science project in their instruction. The

student factor comprises various student needs, as well as experiences they have had with learning outdoors. Contextual factors include testing and accountability policies, the culture of learning, district or school priorities, and school resources, including the school grounds. Our study is motivated by the hypothesis that educative materials designed to support teachers in their relationship with a project will facilitate an experience that is qualitatively different and better than when educative materials are absent.

Study objectives and design

Within Remillard's theoretical framework, our overarching research question is: does the presence of educative support materials influence the likelihood that teachers will enter into a relationship with a citizen science project, and if so, how do the supports function, and what influence do they have in shaping the planned and enacted experience with that project? Three more fine-grained research questions guide the study:

1. Does access to educative supports for a citizen science project influence the extent to which teachers use the project with their students (i.e. the enacted experience)?
2. What types of educative supports do teachers use and value the most as they interact with the project?
3. What features of the citizen science project itself influence how teachers interact with the project and the educative supports?

Setting and sample

Table 1 shows demographic information for study participants ($N = 52$), all of whom teach 5th grade in a southeastern US state. Most participants identified as female and White and have an education degree not specific to science. Overall, our study sample closely resembles elementary teachers in the US (Plumley, 2019; Stromquist, 2018), but it diverges in two important ways. First, the group is relatively experienced, with nearly three-quarters reporting 11 or more years of experience teaching. Second, about 1 in 7 (14%) reported teaching all core subjects to one group of students, compared to 59% of 5th grade teachers nationally (Smith & Craven, 2019). Most teachers in the study described themselves as departmentalised, meaning they teach science (and possibly 1–2 other subjects) to multiple classes of students.

Materials and methods

We selected two well-established citizen science projects for this work: the Community Collaborative Rain, Hail, and Snow Network (known as CoCoRaHS) and the Lost Ladybug Project (abbreviated here as LLP). As both projects lend themselves to data collection spanning the academic year on school grounds, we created a year-long, coherent series of monthly activities (referred to as engagements) that engage students with the data they collect throughout the school year. For example, in an early engagement with CoCoRaHS data, students make sense of daily precipitation measurements from the previous month, exploring trade-offs in how to represent the data (e.g. tables,

Table 1. Participant demographics

	Percent of study participants (N = 52)
Gender	
Female	87
Male	13
Other	0
Race/Ethnicity [†]	
Asian	0
Black or African American	6
Hispanic or Latino	0
Native American or Alaska Native	0
Native Hawaiian or Other Pacific Islander	0
White	92
Prefer not to answer	2
College Degree [†]	
Education	73
Natural Sciences	10
Other	20
Experience Teaching Any Grade K–12	
0–5 years	12
6–10 years	18
11–15 years	26
16–20 years	26
≥ 21 years	18
Experience Teaching Science K–12	
0–5 years	29
6–10 years	18
11–15 years	20
16–20 years	22
≥ 21 years	12
Teaching Assignment	
Teach all core subjects	14
Departmentalised	84
Other	2

[†]Participants could select more than one response option; thus, percentages may add to more than 100.

graphs) and looking for evidence that connects data with significant weather events. Later in the year, students work with a larger data set and use computational tools (e.g. spreadsheets with graphing tools) to explore seasonal variations in precipitation data across regions of the state and consider geographic or seasonal factors that may contribute to the variations. The engagements for each project require ten total days of science instructional time spread throughout the school year.

Each month's engagement also includes educative materials that enhance teachers' content knowledge and pedagogical content knowledge (Shulman, 1986). Our support materials are housed on a website with distinct sections for each project (CoCoRaHS and LLP) and are organised in two broad categories: Front Matter and Engagement-Embedded supports. Front Matter supports offer important 'big picture' information to launch teachers' introduction to the citizen science project. Examples include a concept map that depicts the trajectory of the monthly engagements and science content information specific to teachers. All other supports are in the Engagement-Embedded category. As the name implies, these are embedded within and specific to each engagement. They include activity overviews, depictions of use, and connections to mathematics and literacy. All supports are designed to facilitate productive adaptations as teachers interact with the citizen science project, acknowledging teachers' participatory relationship with the project (Remillard, 2005).

Table 2. Description of front matter support types.

Support type	Description
Concept Map	A graphic representing how the concepts addressed in the monthly engagements relate to one another and concepts outside the scope of the project
Content Resources	A collection of resources (e.g. articles, websites) intended to deepen teachers' knowledge of the science concepts addressed
Media Guide	Digital and print resources appropriate for student viewing that can be used to integrate projects into literacy instruction and provide extension opportunities
Considerations for Outdoor Learning	Guidance on taking students outside for instructional activities, including strategies for setting expectations and questions to consider based on the teacher's context

All support materials were developed using multiple lenses, as described in the literature on educative curriculum materials (Davis et al., 2014, 2017). Each lens translated to a support type. The types are listed and defined in Tables 2 and 3. Examples of two embedded support types are shown in Figure 1, and examples of all support types are included in the Supplementary Materials. The materials were initially drafted by three members of the research team, each a former elementary school teacher, using a design-based-implementation-research (DBIR) approach (Fishman et al., 2013). The materials were reviewed and revised by the entire team and the study's advisory board, all of whom have expertise in citizen science, teacher professional learning, or educative curriculum materials. They were then reviewed by five current classroom teachers (as described in Carrier et al., 2024a), revised, and then piloted by these same teachers. The materials were refined based on teacher feedback throughout this process, then used by the larger group of teachers in the study.

Teachers in the study were asked to use both citizen science projects in their teaching, but they were randomly assigned to receive project-developed support materials for only one project, either CoCoRaHS ($N = 27$) or LLP ($N = 25$). To avoid spill-over between conditions, teachers accessed the support materials through the study's password-protected website, which restricted the materials they could see based on their project assignment. The study allowed only one teacher per school, further guarding against spill-over. Teachers were organised in two cohorts, as shown in the project timeline (Figure 2).

All teachers attended a 2-day summer professional learning experience prior to classroom use. The first session, conducted online, included training videos to orient teachers to both citizen science projects (protocols for collecting data, uploading data to the

Table 3. Description of embedded support types for monthly engagements.

Support type	Description
Overview (labelled 'In a Nutshell')	Overview describing content focus for the month's engagement
Images of Use (labelled 'Narrative')	Descriptive text detailing a hypothetical teacher's approach to using the activity
Science Content and/or Practices	Connections to NGSS and state standards addressed and guidance on incorporating these concepts and related practices
Guidance for Outdoor Learning	Recommendations for preparing students for the outdoor classroom, planning for weather, and organising student resources
Mathematics	Connections to mathematics concepts addressed and related guidance (e.g. possible student preconceptions, instructional strategies)
Literacy	Literacy practices and suggestions for integration
Assessment	Assessment opportunities/suggestions
Citizen Science Connection	Supports for connecting to the work of citizen scientists and contributing data
Extensions	Opportunities for extending learning beyond the month's focus



Export data that students and another location have submitted and allow time to make sense of the data to look for patterns consistent with what students might have discovered during the February activity when considering weather and temperature as factors. Divide students into groups to specifically look at seasonal patterns (using dates in the export) in weather and temperature and connect with the ladybug data. Ask each group to prepare a short class presentation of their findings. Their presentation should include a graph or a drawing to illustrate their findings, document their seasonal ladybug data, and explain why patterns might differ throughout the year. For example, one group could focus on temperature and show how changing temperatures throughout the year impact patterns in the number and variety of ladybugs that are observed. After students have made sense of data collected thus far in the year, have the class make predictions about the species they expect to find and what they expect others reporting data to the project across the state will find in the coming months.





Ms. Jones' Class Notices Patterns

occurred in, perhaps due to their recent study of seasonal variation as part of their weather unit. For example, one student shares that their class seemed most likely to find ladybugs during their search efforts in the fall, highlighting particularly fruitful efforts in late September. This attention to seasons helps Ms. Jones's students identify patterns in temperature and length of daylight that align with seasonal patterns. Ms. Jones uses her document camera to project the observation recording sheets from those three searches, asking students what they notice. One student points out that they recorded temperatures between 71°F and 80°F on each of the days. Another notices that all of the sightings on those days occurred in a raised garden bed where another class was growing spinach. Ms. Jones then shared a recording sheet from early October, in which the class searched but found no ladybugs, asking students what they notice. One recalls that particular search effort, remembering that it had started raining when they were outside, and it felt much colder. Another notes that the temperature they recorded was between 51°F and 60°F. Ms. Jones reminds students that as they review data, it is important to consider temperature or other conditions observed in addition to the date or season. One student jokes, "It's not like the ladybugs have a calendar!" Another adds, "But I bet today *feels* like spring to them! It's very warm today. Maybe we should go out to look!"

As students look at data from earlier in the year, Ms. Jones notices that students are mainly focused on what season the sightings

Figure 1. Sample written teacher supports for LLP.

project website, and accessing project-wide data for analysis). The second session, conducted in person, included hands-on activities to further explore technical aspects of their assigned project, and it introduced the yearlong sequence of web-based support materials for their assigned project. Finally, all teachers participated in monthly 1-h Zoom meetings specific to their assigned project throughout the school year. During these meetings, teachers shared their experiences with each other and project staff-oriented teachers to upcoming engagements.

Data collection and analysis

Within a randomised control trial study design, we collected several kinds of data from all participating teachers and their students at multiple time points. Quantitative data from a weekly instructional log are the basis for findings and claims reported here. All

Years 1–2	Year 3	Year 4
• Develop, pilot, and revise educative support materials • Recruit Cohort 1 and randomly assign teachers	• Cohort 1 participates in summer professional learning • Cohort 1 uses both CS projects and support materials for assigned project • Cohort 1 participates in monthly Zoom meetings • Collect data from Cohort 1 teachers and students • Recruit Cohort 2 and randomly assign teachers	• Cohort 2 participates in summer professional learning • Cohort 2 uses both CS projects and support materials for assigned project • Cohort 2 participates in monthly Zoom meetings • Collect data from Cohort 2 teachers and students

Figure 2. Timeline of the study design.

teachers gave written consent prior to the study and were reminded of their rights at each data collection event. All participating teachers received a weekly email requesting that they complete a brief, online survey (see Supplementary Materials for a copy of the log) that asked what project activities and materials they used that week.

The data presented here come from 52 teachers in two cohorts. The number of weekly logs submitted by each teacher across the school year ranged from 21 to 39 (median = 36, mean = 34.02, SD = 5.37). Computing the maximum possible number of logs is difficult because teachers were asked to complete a log each week, even if school was in session only part of the week. Because planned breaks and unscheduled disruptions (e.g. due to weather) varied across the sample, the number of full and partial weeks also varied. We estimate the maximum possible number of logs to be 39. Monthly averages indicated stable survey participation across the academic year, ranging from 2.29 to 4.59 during the core months of September to May. Submission rates did not decline over time, and inspection of monthly submission patterns showed no evidence that teachers with fewer logs systematically skipped particular weeks or months. Furthermore, log submissions were similar across projects: CoCoRaHS teachers submitted between 22 and 38 logs (median = 37, mean = 35.11, SD = 4.42), whereas LLP teachers submitted between 21 and 39 logs (median = 36, mean = 32.84, SD = 6.11). Although CoCoRaHS teachers submitted slightly more logs on average than LLP teachers, this difference was not statistically significant ($U = 274.500$, $z = -1.166$, $p = 0.244$, $r = 0.162$; Mann-Whitney U test). Furthermore, because weekly logs included items related to both projects and were submitted simultaneously, differential completion by treatment condition was impossible by design. Any missingness therefore occurred at the level of log submission itself and affected both conditions equally.

Teachers also completed an end-of-year survey about their use of study-developed materials and perceived value of the materials. Among other kinds of data collected, all study participants were invited to participate in an in-depth end-of-year interview; 30 agreed. Additionally, 15 teachers were interviewed and observed monthly. We use interview and observation data only to illustrate quantitative results reported here.

Instructional log data were used to measure whether teachers implemented a citizen science project more when they had access to educational supports developed for the

project. Because teachers varied in the number of weekly logs submitted, we calculated the percentage of log entries in which teachers reported their students doing anything with either LLP or CoCoRaHS. This approach standardised the measure of use across teachers and prevented teachers with more frequent log submissions from exerting disproportionate influence on the results. Then, a Mann-Whitney U test was performed to evaluate whether the likelihood of teachers engaging their students with the project differed by whether teachers had access to support materials for the project. We conducted a separate analysis for each project. A Kruskal-Wallis H test was used to explore differences in ratings among teachers' ratings of the usefulness of different types of supports in the end-of-year survey. Because all teachers received the summer professional learning and monthly meetings, we did not analyse the impact of these two supports.

All quantitative analyses were conducted using SPSS Version 29.0.2.0 software. Given the multiple comparisons conducted for this study, there was concern about the false discovery rate. To address this, p -values were adjusted using the Benjamini-Hochberg procedure (Benjamini & Hochberg, 1995), with adjustments applied separately for tests conducted within each dataset – the instructional log and the end-of-year survey – to account for distinct sources of error variance. Throughout the text, adjusted p -values are reported unless otherwise noted. In tables, both original and adjusted p -values are presented, with significance interpreted based on the adjusted values.

Results

Impact of access to educational supports

Teachers with access to supports were significantly more likely than teachers without supports to report their students doing anything with the project, regardless of whether the project was LLP or CoCoRaHS (see Table 4). Both comparisons showed large effects, but the difference was notably greater for LLP than for CoCoRaHS. That is, having access to supports had a stronger impact on project usage for LLP, as evidenced by a larger difference between the without-supports and with-supports conditions (mean ranks of 14.39 and 39.58, respectively) and a greater effect size. In contrast, CoCoRaHS showed higher usage without supports (mean rank of 17.66) and a smaller relative increase with supports (mean rank of 34.69). This provides strong evidence that educative supports positively influence a teacher's relationship with a citizen science project. Interview data illustrate the influence of educative support materials. For example, one teacher described feeling less confident using the project without the support materials:

Table 4. Statistical output from Mann-Whitney U test.

Analysis	Test statistic	Std. Test statistic	Sig.	Adj. Sig. ^a	Effect size
LLP	10.500	−6.018	0.000	0.000*	0.835 ^b
CoCoRaHS	116.500	−4.05	0.000	0.000*	0.562 ^b

^aThe adjusted significance values were calculated using the Benjamini-Hochberg procedure to control the false discovery rate (Benjamini & Hochberg, 1995). Adjustments were applied separately for tests conducted within each dataset to account for distinct sources of error variance.

^bInterpretation of the rank-biserial correlation coefficient is as follows: $r < 0.3$ is a small effect, $0.3 < r < 0.5$ is a moderate effect, and $r > 0.5$ is a large effect (Cohen, 2013).

*Indicates a statistically significant result.

Lost Ladybug, I'm much less confident because I haven't had any [study-developed supports], and so that makes a huge difference. I feel like I'm floundering with that one. (CoCoRaHS Teacher)

Use and value of educative support types

Use of front matter supports

When teachers reported in the weekly log that their students had done anything with the citizen science project for which they had support, the log asked them which, if any, of the Front Matter supports they had used. On average, teachers reported using at least one Front Matter support in 41.9% of their logs (Table 5). This relatively low percentage was expected, as Front Matter supports are materials teachers might use only once. Though all supports are linked within the TL4CS website, Front Matter supports are separated from the monthly engagements and are less visible. LLP teachers used the Front Matter supports more than CoCoRaHS teachers did (Table 5). LLP teachers reported using at least one of the Front Matter supports in 51.5% of their logs, compared with 32.9% of the logs of CoCoRaHS teachers, a significant difference ($U = 190.000$, $z = -2.702$, adjusted $p = 0.011$, $r = 0.375$; Mann-Whitney U test).

There was also a significant difference in how frequently teachers reported using different types of Front Matter supports ($\chi^2 = 25.198$, adjusted $p < 0.001$, $\epsilon^2 = 0.107$; Kruskal-Wallis H test). For example, combining across both projects, use of Content Resources was significantly higher than use of the Concept Map and the Media Guide (Table 6). Use of Considerations for Outdoor Learning was significantly higher than use of the Media Guide. Given elementary teachers' low perceptions of their preparedness to teach science relative to other subjects (Plumley, 2019), their use of Content

Table 5. Mean percentage of logs in which teachers reported using front matter supports.

Type of front matter support	All (N = 52)	LLP (N = 25)	CoCoRaHS (N = 27)
Content Resources	26.4	34.3	19.1
Considerations for Outdoor Learning	18.6	24.8	12.8
Concept Map	12.9	12.0	13.8
Media Guide	8.9	14.4	3.8
At least one support	41.9	51.5	32.9

Table 6. Statistical output from post hoc comparisons using Dunn's test.

Comparison	Test statistic	Std. test statistic	Sig.	Adj. Sig. ^a	Effect Size
Content Resources v. Concept Map	-38.904	-3.339	0.001	0.002*	0.232 ^b
Content Resources v. Media Guide	55.442	4.758	0.000	0.000*	0.330 ^b
Content Resources v. Considerations for Outdoor Learning	-20.462	-1.756	0.079	0.093	0.099 ^b
Considerations for Outdoor Learning v. Media Guide	34.981	3.002	0.003	0.006*	0.208 ^b
Considerations for Outdoor Learning v. Concept Map	-18.442	-1.583	0.114	0.124	0.110 ^b
Concept Map v. Media Guide	16.538	1.419	0.156	0.162	0.098 ^b

^aThe adjusted significance values were calculated using the Benjamini-Hochberg procedure to control the false discovery rate (Benjamini & Hochberg, 1995). Adjustments were applied separately for tests conducted within each dataset to account for distinct sources of error variance.

^bInterpretation of the rank-biserial correlation coefficient is as follows: $r < 0.3$ is a small effect, $0.3 < r < 0.5$ is a moderate effect, and $r > 0.5$ is a large effect (Cohen, 2013).

*Indicates a statistically significant result.

Resources is not surprising. Additionally, prior to joining the study, half the teachers said they rarely took their students outside for science instruction, so their reliance on Considerations for Outdoor Learning is also plausible.

Interview data illustrate why some teachers returned to Front Matter support throughout the year. One teacher explained how the guidance in Considerations for Outdoor Learning helped students maintain focus in a novel learning environment:

The outside learning [supports] ... is something I've never really seen before. That was probably, oddly enough, my favourite [support] of all of them that I use probably every single week, because taking 30 children outside and maintaining concentration while right behind you, there are classes at recess, because where we had to put the rain gauges was right at the edge of the playground. (CoCoRaHS Teacher)

Use of engagement-embedded supports

We followed the design principles described earlier when choosing types of engagement-embedded supports to develop for each engagement. Consequently, not all types of supports are represented equally for each project. Three types appeared in all nine monthly engagements in each project: In a Nutshell, Narrative, and Science content. We considered only these three supports in our analysis. As shown in Table 7, some supports were used more than others ($\chi^2 = 25.401$, adjusted $p < 0.001$, $\epsilon^2 = 0.151$). Use of In a Nutshell was significantly higher than Narrative and Science Content, with use of Science Content significantly higher than Narrative (Table 8). This rank order was consistent across both LLP ($\chi^2 = 719.658$, adjusted $p < 0.001$, $\epsilon^2 = 0.239$) and CoCoRaHS ($\chi^2 = 87.736$, adjusted $p = 0.027$, $\epsilon^2 = 0.072$), although there were slight differences in post hoc significance patterns. Despite these minor differences, the overall trend remained the same: In a Nutshell was used most frequently, followed by Science Content and the Narrative.

Interview data illustrate how teachers used different supports. For example, one teacher explained how In a Nutshell provides a high-level view of the engagement, while the Narrative and Science Content offer more fine-grained guidance:

In a Nutshell is always my first go-to, and then I like to look at [the Narrative] just to get an interpretation of how that may have been presented. ... And this year, because I'm so new to it, and this is my second year in 5th grade, I do tend to ... start with the (Science Content). Then I like to see the other connections with other topics because it can be sort of intertwined with the other subjects. (LLP Teacher)

Teachers completed an end-of-year survey about their experience with their citizen science project and were asked to rate the value they found in each type of Engagement-Embedded support using a four-point scale (1, not at all valuable; 2, minimally valuable; 3, moderately valuable; 4, very valuable). Their overall median ratings suggest high perceived value for each type of support (Table 9) as well as differences

Table 7. Mean percentage of logs in which teachers reported using embedded supports.

Type of embedded support	All (N = 52)	LLP (N = 25)	CoCoRaHS (N = 27)
In a Nutshell	33.1	43.8	23.1
Science Content	22.3	22.4	22.2
Narrative	12.3	11.7	13.0

Table 8. Statistical output from post hoc comparisons using Dunn's test.

Analysis	Test statistic	Std. test statistic	Sig.	Adj. Sig. ^a	Effect size
Across Projects					
In a Nutshell v. Narrative	44.452	5.037	0.000	0.000*	0.403 ^b
In a Nutshell v. Science Content	21.000	2.380	0.017	0.023*	0.191 ^b
Science Content v. Narrative	23.452	2.658	0.008	0.012*	0.213 ^b
LLP					
In a Nutshell v. Narrative	26.580	4.385	0.000	0.000*	0.403 ^b
In a Nutshell v. Science Content	16.740	2.762	0.006	0.010*	0.319 ^b
Science Content v. Narrative	9.840	1.623	0.105	0.119	0.187 ^b
CoCoRaHS					
In a Nutshell v. Narrative	16.111	2.517	0.012	0.017*	0.280 ^b
In a Nutshell v. Science Content	1.500	0.234	0.815	0.815	0.026 ^b
Science Content v. Narrative	14.611	2.283	0.022	0.027*	0.254 ^b

^aThe adjusted significance values were calculated using the Benjamini-Hochberg procedure to control the false discovery rate (Benjamini & Hochberg, 1995). Adjustments were applied separately for tests conducted within each dataset to account for distinct sources of error variance.

^bInterpretation of the rank-biserial correlation coefficient is as follows: $r < 0.3$ is a small effect, $0.3 < r < 0.5$ is a moderate effect, and $r > 0.5$ is a large effect (Cohen, 2013).

*Indicates a statistically significant result.

Table 9. Median ratings of value of engagement-embedded supports.

Type of embedded support	All (N = 52)	LLP (N = 25)	CoCoRaHS (N = 27)
In a Nutshell	4.00	4.00	4.00
Science Content	3.00	3.00	3.50
Narrative (i.e. Ms. Clark or Ms. Jones)	3.00	3.00	4.00

in ratings among the three types ($\chi^2 = 11.038$, adjusted $p = 0.024$, $\epsilon^2 = 0.059$; Kruskal-Wallis H test). Post hoc comparisons indicated that ratings of In a Nutshell were significantly higher than Science Content and the Narrative (Table 10). Overall, teachers' ratings of value align with their reported use of each support type. When examining the median ratings within each project, teachers' ratings were significantly different in LLP but not in CoCoRaHS. The results of post hoc comparisons in LLP showed the

Table 10. Statistical output from post hoc comparisons using Dunn's test.

Analysis	Test statistic	Std. test statistic	Sig.	Adj. Sig. ^a	Effect size
Across projects					
In a Nutshell v. Science Content	21.039	2.663	0.008	0.018*	0.215 ^b
In a Nutshell v. Narrative	24.108	3.052	0.002	0.018*	0.247 ^b
Science Content v. Narrative	3.069	0.388	0.698	0.698	0.031 ^b
LLP					
In a Nutshell v. Narrative	15.640	2.756	0.006	0.018*	0.318 ^b
In a Nutshell v. Science Content	12.260	2.160	0.031	0.047*	0.249 ^b
Science Content v. Narrative	3.380	0.596	0.552	0.621	0.069 ^b
CoCoRaHS					
In a Nutshell v. Narrative	8.673	1.582	0.114	0.171	0.179
In a Nutshell v. Science Content	8.808	1.606	0.108	0.171	0.182
Science Content v. Narrative	-0.135	-0.025	0.980	0.980	0.003

^aThe adjusted significance values were calculated using the Benjamini-Hochberg procedure to control the false discovery rate (Benjamini & Hochberg, 1995). Adjustments were applied separately for tests conducted within each dataset to account for distinct sources of error variance.

^bInterpretation of the rank-biserial correlation coefficient is as follows: $r < 0.3$ is a small effect, $0.3 < r < 0.5$ is a moderate effect, and $r > 0.5$ is a large effect (Cohen, 2013).

*Indicates a statistically significant result.

same pattern as the overall finding: In a Nutshell was perceived as more valuable than Science Content and the Narrative.

Comparing the use of front matter and engagement-embedded supports

Front Matter and Engagement-Embedded supports were not used equally by teachers. When the weekly log asked about their use of each type of support that week, teachers had the option of choosing ‘none of the above,’ which they did in an average of 56.8% of their logs for Front Matter supports and only 9.0% of their logs for Engagement-Embedded supports (Table 11). This pattern of significant difference (Table 12) was evident in both LLP and CoCoRaHS, indicating that teachers consistently reported greater use of Engagement-Embedded supports regardless of project.

Interview data offer insight into why teachers used Front Matter supports less frequently than Engagement-Embedded supports. Teachers explained that both kinds of supports served a function, but the Engagement-Embedded supports provided just-in-time guidance that teachers needed to enact engagements. One teacher described:

I used the Front Matter when I [met with my principal to show] this is what I was doing as part of my personal development plans and how it tied into the course of study. But then the [Engagement-Embedded] stuff I used all the time because it was all in one convenient location. I didn’t have to look around. I always knew where it was since it was embedded. (CoCoRaHS Teacher)

Teachers’ interactions with CS projects and educative supports

One theme that runs through the results is the effect of the citizen science project itself. We described earlier that although access to support materials positively impacted teachers’ use of both projects, the effect was greater for LLP. Log data also reveal that regardless of access to support materials, teachers were much more likely to use CoCoRaHS than LLP with their students. Typically, students collected data for LLP no more than weekly and often much less frequently. In contrast, data collection for CoCoRaHS tended to occur daily. Log, interview, and observation data strongly suggest this is due

Table 11. Mean percentage of logs in which teachers reported using none of the provided supports.

Type of support	All (N = 52)	LLP (N = 25)	CoCoRaHS (N = 27)
Front Matter	56.8	46.9	66.1
Embedded	9.0	9.7	8.4

Table 12. Statistical output from Mann-Whitney U test.

Analysis	Test statistic	Std. test statistic	Sig.	Adj. Sig. ^a	Effect size
Across Projects	178.000	−7.693	0.000	0.000*	0.754 ^b
LLP	65.500	−4.850	0.000	0.000*	0.687 ^b
CoCoRaHS	22.500	−5.942	0.000	0.000*	0.809 ^b

^aThe adjusted significance values were calculated using the Benjamini-Hochberg procedure to control the false discovery rate (Benjamini & Hochberg, 1995). Adjustments were applied separately for tests conducted within each dataset to account for distinct sources of error variance.

^bInterpretation of the rank-biserial correlation coefficient is as follows: $r < 0.3$ is a small effect, $0.3 < r < 0.5$ is a moderate effect, and $r > 0.5$ is a large effect (Cohen, 2013).

*Indicates a statistically significant result.

to how teachers organised their students for data collection. More than half of log entries for LLP reported all or almost all students being involved in data collection, compared to fewer than a quarter of the log entries reporting all students participating at once for CoCoRaHS. Usually, teachers were able to mount a CoCoRaHS rain gauge on their school grounds close enough to their classroom so that they felt comfortable sending a pair of students to read and empty the rain gauge daily without supervision. In contrast, searching for ladybugs generally required venturing farther from the classroom, and supervision was essential. Teachers organised whole-class searches, which required preparation, including gathering supplies, following safety protocols, and, in some cases, obtaining approval from the school administration.

Other project-related factors affected participation, including the effort required to enter observations on each project's website. For CoCoRaHS, data entry involved recording the observation date and time and the precipitation amount. This required as little as a minute and was easily accomplished by 5th grade students. The data entry form on the LLP website required much more data entry, including uploading a photo. Teachers typically entered class observations for LLP themselves rather than having students do it. Access to data was another factor. In CoCoRaHS, when students uploaded their day's data, they could immediately view their observation on a map along with observations from all CoCoRaHS stations (over 20,000). Students could also easily mine the CoCoRaHS website for historical data. In contrast, LLP was unable to process any submitted data during the time of our data collection due to a reduction of staff, so students' observations never appeared online. These findings highlight both the complexity of SBCS and the project-related factors that shape how teachers are able to incorporate citizen science projects in their science instruction.

Discussion

The potential of educative features to facilitate a teacher's participatory relationship with a citizen science project

We return now to Remillard's model of a teacher's participatory relationship with their curriculum (Remillard, 2005). In the model, we replaced curriculum materials with a citizen science project to study the impact of educative support materials and to explore the theory's utility in a novel problem space (i.e. integrating citizen science in elementary science instruction). In designing support materials for citizen science projects, we closely followed the research on educative curriculum materials – which was also based on Remillard's model – and the recommendations emerging from that work, (e.g. Arias et al., 2016; Davis et al., 2014, 2017). Our data support findings from this work. Educative features had a large positive impact on the frequency of teachers' use of a citizen science project with their students. Teachers reported that the educative materials saved them time and effort. Consistent with Remillard's model and design principles for educative curriculum materials (Davis et al., 2017), we built our materials acknowledging that teachers would adapt them, and teachers adapted them. We also followed the principle of constructing a suite of supports, acknowledging that each teacher's relationship with their project would be unique, shaped by their own personal attributes, their students, and their unique context. Consistent with other research, we found that

some supports were used most frequently, but that there was variation. Like Arias et al. (2016), we found that teachers gravitated towards supports that helped them envision lesson enactment (In a Nutshell and Narrative) and identify important science concepts to highlight (Science Content). These findings suggest Remillard's model is applicable in a novel space.

Our work further suggests that Remillard's model should be revised to guide future research and development in SBCS. The most obvious change is replacing the curriculum component with the citizen science project. Remillard identified features of a curriculum that influence a teacher's participatory relationship, including representations of concepts and tasks, structures, voice, and look. Similarly, our work suggests features of the citizen science project are important to consider. These include alignment with science standards, ease of data collection, grade-level appropriateness, access to data collected by students and others, and appeal to students (Goforth et al., 2026). We also identified features of the context that influenced teachers' relationship with the project. Both projects in our study involved collecting data on the school grounds, so issues of access to and safety of outdoor spaces on the campus were paramount. Administrator support for outdoor learning specifically and for citizen science more broadly was also essential. School district pacing guides, to which most teachers in our study were subject, tended to work against citizen science. Other researchers have found that pacing guides limit teacher autonomy and narrow both the content taught and the strategies used (Cobb et al., 2003; Wills & Sandholtz, 2009). Other contextual factors, such as time for science and accountability pressures, seemed equally important whether teachers were engaging with a science curriculum or with citizen science. Similarly, the teacher factors Remillard identified are equally applicable, including content knowledge, subject matter knowledge, perceptions of students, and tolerance for discomfort (Remillard, 2005).

Study limitations

Although random assignment of teachers controlled for many variables, it did not eliminate all sources of bias. All our teachers are in one Southeastern US state. Our recruitment also relied on teachers who self-selected into the study, so our sample may be biased towards participants willing to incorporate citizen science into their science instruction, a practice none had explored previously. Thus, our findings may generalise only to teachers who are inclined to try new practices. However, because the materials used most frequently by elementary teachers in the US are ones they create themselves (Doan et al., 2023), it is reasonable to assume that they look for high-quality resources to support their science instruction and may be receptive to trying citizen science with their students. We also acknowledge that our sample is not fully representative of 5th grade teachers nationally, most of whom teach all core subjects to one group of students (Smith & Craven, 2019). In contrast, 84% of our study participants teach in departmentalised situations, where they provide science instruction to more than one group of students. That said, based on interviews with and observations of study participants, the materials appeared to work well regardless of instructional form. Those teaching science and other core subjects were able to tie the project to multiple disciplines, including literacy, mathematics, and social studies (Carrier et al., 2024b; McGowan et al., 2025; Scharen et al., 2025).

Another limitation relates to the study instruments. The instructional log is a coarse measure of project use. Observation and interview data confirm that teachers' enactments varied widely in each project. That said, those same data support the quantitative findings reported here. Carrier et al. (2024a), for example, describe in depth how two teachers in our study took up the educative supports in their science instruction, describing multiple factors that shape the teachers' and students' experience with citizen science.

All teachers received one day of professional learning on their project-specific support materials and had access to monthly 1-h meetings with other teachers in their treatment condition. The amount of support made available through these two activities was quite small relative to the amount made available through the educative support materials. However, we cannot disentangle their effects from the effect of the support materials alone.

Although our study design allows for causal claims about the effect of educative supports on the frequency of use of citizen science projects by teachers, the data presented here do not support claims about the quality or nature of engagement. As we have reported elsewhere, teachers' use of citizen science projects varies widely, even when they have access to educative supports (Carrier et al., 2024a; Scharen et al., [Under review](#)).

A final limitation includes the limited functions of the LLP website. The relatively complex data entry form and teachers' inability to access data due to the project's funding-related limitations may have influenced how they interacted with the project. As such, teachers may have been less likely to engage with some of our project supports when they were not able to compare their data to other entries. Our supports were designed to create connections between our participants' data and other schools' data, and the inability to access others' data meant that they couldn't complete some of the sense-making activities as written. If data were accessible as originally planned, the self-reported data on engagement with project materials may have differed. While we were not able to manage the teachers' access to LLP website data during this study, we addressed this concern for future users of our materials by developing a new citizen science project called Ladybugs at School in the well-established iNaturalist platform. This new citizen science project was created by a member of our research team who is an entomologist and has extensive experience in the field as the head of citizen science at a science museum. Similar to LLP, teachers and students report their findings of local ladybug species and can easily see their own and others' data through the platform. The shift from LLP to Ladybugs at School will allow teachers to continue using our support materials and access their data. Future studies may consider how this impacts teachers' and students' engagement with citizen science projects.

Conclusions

Our findings support the hypothesis that motivated the study, specifically that educative materials designed to support teachers' relationship with a citizen science project positively impact the frequency with which teachers use the project. Our findings indicate that although teachers use these support materials, some types are used more than others. We see two broad implications from our findings for the citizen science community: one for those who study SBCS and one for those who design citizen science projects and want contributions from students in formal education settings.

Among the implications for researchers, Remillard's model should be further explored to better understand how it can support research on SBCS. Many researchers have used the model to study teachers' adaptation of curriculum materials. Our literature review suggests we are the first to apply it to SBCS. We found great utility in the model within the context of SBCS, but much work is needed to understand (1) which factors and which relationships among factors are most influential and (2) which of these can be addressed through educative support materials and other kinds of support. We have evidence that support materials can help teachers who have limited experience taking their students outside for science instruction by giving them practical guidance. It is less clear how such materials can help teachers work within the constraints of district pacing guides that they must often follow.

A second implication for researchers is how teachers' use of citizen science projects changes with time. We studied our teachers' use of citizen science projects for one year, and we followed a smaller group into their second year of use. Teachers received financial incentives for participating, and some of our study features (e.g. the weekly log and monthly meetings) likely made teachers feel accountable for using the projects. The field needs to understand whether and how teachers' use of a citizen science project changes when external incentives and accountability, like those included in our study, are absent.

Finally, we believe SBCS can add authenticity to teachers' science instruction, but we do not see it replacing teachers' ongoing science instruction. We suspect that collecting, reporting, and analysing authentic data over an entire school year is more likely to give students an accurate picture of scientific inquiry than a four-week unit on weather and climate or ecosystems, but both kinds of instruction are important. However, the structure of published instructional materials and pacing guides work against teachers who want to facilitate students' long-term investigations. The field needs to understand how elementary teachers can successfully integrate long-term engagement in citizen science projects with their ongoing science instruction.

Grant funding allowed us to devote considerable amounts of resources and time to developing the supports. Most citizen science projects will not be able to do the same. Therefore, we recommend that project developers with limited resources prioritise the types of supports that teachers are most likely to use. Overarching guidance (what we call Front Matter) is important for helping teachers understand the arc of an extended series of investigations and a place to show teachers how the project can address the standards they are responsible for teaching. Teachers also need guidance on how to weave the project into their instruction. We approached this through monthly engagements with the data students and other project participants had collected. Our teachers gravitated towards the activity overviews (In a Nutshell) and the narrative accounts of a hypothetical teacher. This finding is consistent with other research on how teachers incorporate an innovation in their instruction (e.g. Loucks-Horsley et al., 2003). In addition, if a citizen science project places novel demands on teachers, such as taking students outdoors or introducing computational tools to analyse project databases, teachers need support for navigating these.

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Ethics statement

This research met ethics requirements with Horizon Research, Inc.'s Institutional Review Board approval #00005913.

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