horizon RESEARCH, INC.

Factors Affecting Teachers' Decisions to Integrate Citizen Science Into Classroom Instruction

Meredith L. Hayes
P. Sean Smith
W. Robert Midden

April 2020

TABLE OF CONTENTS

Page

INTRODUCTION

Increasingly, CS is making its way into schools. An article in *NSTA Reports* highlights teachers' experiences incorporating CS into their classrooms (NSTA, 2018), ranging from kindergarteners identifying monarch eggs and larvae to secondary students mentoring younger students as they examine local watersheds. Science instruction is the most natural place to introduce CS in schools, and national data suggest that students would benefit from participating in CS as a means of gaining authentic science experiences. In 2018, only 26 percent of elementary teachers and 46 percent of middle grades teachers reported placing a heavy emphasis on learning how to do science (develop scientific questions; design and conduct investigations; analyze data; develop models, explanations and scientific arguments) (Banilower et al., 2018). With many states adopting the Next Generation Science Standards ([NGSS]NGSS Lead States, 2013), instruction is shifting to be "3-dimensional," integrating crosscutting concepts, science and engineering practices, and disciplinary core ideas. CS projects have the potential to engage students in this kind of learning.

The National Academies of Sciences, Engineering, and Medicine (NASEM) Committee on Designing Citizen Science to Support Science Learning recently analyzed the available STEM education literature and reported their findings regarding the nature of CS and the principles that govern its effectiveness. Their report states, "As an emerging field, citizen science has opportunities to grow, to contribute to what we know about how people learn science, and to broaden participation in science" (NASEM, 2018, p. 10).

Many projects welcome student participation, but when students do not understand why they are collecting data, why they are collecting data in a particular way, or what the data could mean when analyzed appropriately, CS does not achieve its potential to engage students in meaningful science learning. The NASEM (2018) CS report concludes that while there is some evidence that CS can enhance learning, much more evidence is needed to document this and to identify the factors that best promote mastery of the various learning outcomes that can be achieved in CS.

Classroom teachers are uniquely positioned to shape how students experience CS. In well-implemented, school-based CS, students learn core concepts and can develop a deeper understanding of the nature of scientific inquiry by engaging in science practices, including planning and carrying out investigations, analyzing and interpreting data, constructing explanations and models, and reporting their conclusions to various stakeholders, including the scientific and local communities.

CONTEXT

Recognizing the educative potential of CS and the unique position of classroom teachers, CS in Schools (CSiS),[1] a recent six-year-long program located in the upper Midwest of the US and funded by the National Science Foundation, aimed to test the effect of integrating CS into classroom instruction on student motivation, engagement, and learning in two collaborating school districts.

CSiS included two cohorts of teachers for three years each. Most Cohort 1 participants, those teaching grades 3–5, taught multiple subjects to one group of students, whereas the majority of Cohort 2 participants (who teach grades 6–8) were departmentalized.

The program's theory of action included three main components: inquiry-based instruction, CS, and collaboration among participants. All CSiS activities and outcomes were aligned with at least one of these components. In each cohort's first year, beginning with a multi-day summer institute, the program introduced participants to the 5E Model of instruction (Engagement, Exploration, Explanation, Elaboration, and Evaluation) (Bybee et al., 2006) and focused on engaging teachers with science content and inquiry-based teaching practices. In addition to providing teachers with physical kits and printed instructional materials for Cohort 1 and various commercially published materials for Cohort 2), CSiS staff offered several hours of kit-focused training and ongoing support through academic year professional development sessions to facilitate effective implementation.

Equipped with a year of experience implementing inquiry-based instruction, each cohort was introduced to their CS project during their second summer institute. Each project was intended to engage students in research designed to address questions of both scientific significance and local relevance. For example, the 3rd and 8th grade CS projects involved monitoring bees and butterflies to collect and analyze population data; 5th and 7th graders assessed local water quality. Based on its theory of action that students are motivated by the opportunity to make meaningful contributions to their community, CSiS leaders hypothesized that implementing these projects would enhance student motivation and engagement in learning science (Astin et al., 2000; Lee, 2003). Participating teachers and students, guided by professional scientists who were leading each project, presented their research in symposia, typically held at the end of the school year, as a way to disseminate their findings with a local audience.

Collaboration was also a major focus of the program, as CSiS brought together several schools across two school districts. Participants from each district regularly interacted during professional development sessions and in program-established formal participant networks. The

[1] CS in Schools (CSiS) is a pseudonym, as are all names in the article.

program envisioned that teachers would inspire and support one another in providing effective science instruction.

STUDY DESIGN

We conducted case studies (Yin, 2003) of six science teachers: three from Cohort 1 and three from Cohort 2. Case study participants were purposively selected to maximize variation in grade level, school, and district. Although many characteristics among the cases varied, one commonality (ensured by the program's decision to first implement activity-based science curricula) was that each participant had at least one year of experience teaching inquiry-based science.

Though familiar with CSiS since it began, members of the research team were not involved in developing or implementing program activities. The case studies were designed to provide an in-depth view of program impact and sustainability, addressing the following research questions:

(1) How did the teacher's engagement with the program (i.e., inquiry-based instruction, CS, and collaboration) evolve?

(2) What was the teacher's vision for future engagement in program-related initiatives (i.e., sustainability)?

(3) What accounted for the teacher's evolving and sustained engagement?

As indicated by the research questions, our broader research focused on teachers' experiences in CSiS and what would need to be in place for continued implementation of CS. However, the factors that account for teachers' sustained engagement reflect conditions that would have been helpful to have in place from the beginning. Therefore, this article focuses on findings related to our third research question, as the principles gleaned from these cases can inform both those who are beginning and in the midst of school-based CS implementation.

Data collection for the case studies consisted of classroom observations, in-depth interviews, and a survey. One class period of each teacher's instruction was observed in spring 2018, scheduled at teachers' convenience. Following the classroom observation, a researcher conducted an initial telephone interview with each teacher to determine whether this class period was typical of her/his science instruction, and explored the impacts of CSiS on teachers, their science instruction, and collaboration, as well as factors affecting teachers' use of CSiS-promoted practices (e.g., inquiry-based instruction, CS).

Several weeks after the first interview (during which data from the first interview were analyzed), teachers were contacted for a follow-up interview, which began with the researcher summarizing the teacher's experience in CSiS (e.g., impacts, facilitating factors, and challenges over the course of their involvement) and asking each teacher whether the account accurately depicted their experience. The remainder of the second interview consisted of follow-up questions related to collaboration, inquiry-based instruction, and CS. All interviews were recorded and transcribed.

The survey was administered to all CSiS participants at the end of the 2017–18 school year. For this study, the most salient survey questions related to science teachers' reports of how they allocated time to CS in their science instruction. Teachers were asked to estimate the percentage of science instructional time spent on CS, and what percentage of that time was spent on various components of CS (e.g., data collection, data analysis, or sense making).

Analysis of case study data began with a member of the research team summarizing the key themes that emerged within and across interviews. Because CS was the centerpiece of CSiS's theory of change, the analysis focused intensively on the likelihood of teachers sustaining their use of CS and factors influencing the sustainability of CS.

As described above, the cases draw on all three types of data: interviews, observations, and survey responses. One researcher drafted all of the case reports. Each case was then read by at least one other member of the research team, and in instances of disagreement about the analysis, team members met to resolve them. Each teacher also reviewed a draft of their case for accuracy as a means of member checking (Lincoln & Guba, 1985). No revisions resulted from this process.

Of the six cases, we selected two to illustrate themes apparent across all. Following the two cases is a cross-case analysis identifying factors that facilitated and inhibited teachers' uptake and sustained implementation of CS. In addition to identifying these factors, we outline conditions likely to support effective implementation and discuss implications for those involved in supporting school-based CS.

CASES

In each of the cases that follow, we begin by noting how each teacher got involved in CSiS and briefly describe their classroom instruction that we observed. We then discuss how their instruction evolved during their participation, attending in particular to their implementation of CS and factors that influenced their decisions. All names are pseudonyms. Case titles were created inductively to capture the teacher's experience in the project.

Ms. Simon: Pollinating Student Interest

Ms. Simon, an experienced 3rd grade teacher who teaches all subjects, joined CSiS due to a personal interest in science. On the day a researcher visited Ms. Simon's classroom, students were working in pairs to gather information online about various weather-related topics (e.g., cloud types, tornadoes, floods). Ms. Simon planned to have students compile information on their topic into a short presentation. Ms. Simon intended for the lesson to be an extension of water and climate investigations that the class recently completed, though she acknowledged that the research activity aligned more with her English Language Arts standards.

According to Ms. Simon, years of low student performance on a state-mandated 5th grade science test motivated her district's participation in CSiS. Prior to CSiS, elementary science instruction included limited opportunities for student inquiry. As she put it:

> *We're driven by testing. Fifth grade used to take a science test. What we found, as a general trend, is the results were horrible, because the kids—they didn't think of themselves as scientists. Science was just something you read and you do a worksheet. It varies from classroom to classroom…. I think that the district looks at the whole CSiS [project] as a way to, number one, get kids excited about school, because it's very motivating, and number two, to raise up those test scores for the 5th grade science test.*

Although Ms. Simon still wishes for more time to teach science, she stated that the time currently allotted is an improvement over her circumstances prior to CSiS. Ms. Simon began incorporating CS into her instruction through a pollinator project. Prior to CSiS, Ms. Simon and her students raised monarch butterflies, but in the context of CS, she observed that her students were more involved, as opposed to solely observing. As she described:

> *Before, it was more the kids just could observe. It wasn't quite as sensory. Now it's sensory. They get to touch them and put stickers on their wings, and let them go. Before, it would just be a few—I just basically did it to just teach insect life cycles, whereas now, they're really passionate about it, because we know that the monarch population is dwindling year after year.*

Ms. Simon indicated that she devoted a considerable proportion of her science instructional time to CS during her first year of implementation, and even more time the following year. However, two years later, Ms. Simon reported spending far less time on CS than she had during her formal involvement in CSiS. There have also been changes in how she allocates the time she spends on CS. For example, the proportion of time spent collecting data has steadily decreased, while time spent on other activities related to CS (e.g., learning how to use scientific instruments, reading stories or articles about the topic) has increased substantially.

During her first three years of involvement in CSiS, Ms. Simon taught at Maple Elementary, where an on-site pollinator garden was installed by the CS professional scientist. However, following the 2016–17 school year, Maple Elementary was demolished, and Ms. Simon and several other CSiS participants were moved to a temporary school site, which does not have a pollinator garden. Not having an on-site garden has inhibited Ms. Simon's ability to engage students in the pollinator project, also contributing to the decreased CS time. As she said:

> *Our building was demolished, and we were housed in a temporary building. We left behind our pollinator garden, and we didn't have—I did manage to bring in the monarchs in the fall and let the kids tag the monarchs. Five of our monarchs were actually recovered in Mexico, so that's pretty amazing. We didn't have the real hands-on—we couldn't go out and look at the different bumblebees, and we had done that before at the other building.*

Ms. Simon also described weather-related challenges (an unusually cold spring) in 2017–18 that may further explain these fluctuations in CS time and focus. Despite these setbacks, Ms. Simon considers the CS pollinator project an important part of her 3rd grade instruction and feels strongly about continuing to engage students in this project. For example, left without an on-site garden, she took matters into her own hands and planted four planter boxes with native plants at her current school. She hopes that the planters will be able to serve as a small-scale pollinator garden for students to use for CS:

> *I collected seeds, and that's how we got seeds. I just did this on my own, without saying anything to anybody. We do have some of the exact genetic plants that were in that pollinator garden that I collected…. I grow a lot of milkweed myself, because I've really gotten into this butterfly thing in my own time…. As far as having full-grown plants for the kids to go out and observe the different kinds of pollinators, and learn the difference between the carpenter bees and the bumble bees, and report into Bumble Bee Watch, we couldn't do that [this year]. Now, next year, hopefully with these little boxes that we have…. By fall, we should have some blooming plants that came from the old pollinator garden.*[2]

In addition, Ms. Simon explained how the CS project has enabled her to fulfill requirements related to her district's project-based learning (PBL) initiative:

> *PBL and CS, really they go hand-in-hand if it's in science…. It's always trying to get more bang for your buck with the minutes you have in a day…. It's like, 'We're going to do this anyway, so we might as well just take it a little bit more in depth and call it this, too. We're going to satisfy two requirements.'*

---

[2] Bumble Bee Watch is a CS project in which students upload photographs and information about bees they see in their area.

Ms. Simon attributes increased student engagement in science over the past several years to CS, further encouraging her to continue with the project. For example, when she asked her students to share their favorite moments of the school year, releasing the monarch butterflies they had raised was at the top of the list. As she said, "On the last day of school, when we hadn't seen a monarch since October, the kids were still thinking about it."

Collegial support has also influenced Ms. Simon's CS implementation. As a group, Ms. Simon and her colleagues appear committed to continuing CS and willing to put forth additional effort to sustain their project. As she described:

> *I have a tent in my yard, and I probably have 100 caterpillars, and I collected 30 eggs yesterday. Over the summer now, both of my colleagues grow these different kinds of milkweed that I grow, because I've provided plants for them. They'll take some caterpillars and just raise them into butterflies with their kids. It's not really like this is schoolwork that we're doing. This is like, "Let's help the butterflies, so there's more butterflies."*

Positive publicity surrounding their pollinator project has also translated into administrative support. Ms. Simon acknowledged that while reading instruction remains a top priority, particularly in 3rd grade, administrators show a great deal of support for science as well:

> *We've got nothing but support, as long as we're also working with our reading. Reading is the big thing for our school, and for our district, too, because we get that state report card. We were in the paper when we were releasing butterflies. There was a big write-up in the paper. The top administration, they like all that positive stuff, so they've also been supportive of CSiS.*

Although Ms. Simon finds school and district administrators supportive, their support seems to be an additional benefit, rather than a requirement for CS to continue. Ms. Simon expressed confidence that she and her colleagues will be able to continue with CS in the future, sharing that although she appreciated the support of professional scientists, she feels comfortable continuing on her own. In her words:

> *[Our CS scientists] were more like a guide on the side. We don't really rely on them. I mean, we figured a lot of things out on our own. I'm pretty confident, and I'm pretty confident that I speak for my colleagues in my grade level, as well.*

Overall, Ms. Simon is confident that she can implement CS in her instruction and has found ways to navigate external factors that impact her ability to engage students in the project. Despite a period of transition, including the destruction of the pollinator garden and a move to a new building, Ms. Simon has remained committed to including CS in her instruction. She hopes to establish a permanent pollinator garden once she settles into her new school building. In addition, she is optimistic that the enthusiasm that she and her colleagues have for CS will transfer to other teachers.

Ms. Mitchell: Contagious Enthusiasm

Ms. Mitchell, an experienced 8th grade teacher, is responsible for teaching science to multiple classes each day at Franklin Middle School. Hearing about Cohort 1's involvement with CSiS piqued Ms. Mitchell's curiosity about how the program could help her improve her instruction. She joined the second cohort at its start, in spring 2015.

On the day that we visited Ms. Mitchell's classroom, students conducted an investigation from a commercially published module about genetics. Specifically, students were provided with different tools (e.g., spoon, clothespin) to represent various beak types and different "foods" (e.g., rice, marbles, marshmallows). Before they began, Ms. Mitchell asked them to make predictions relating beak type to types of food most easily collected.

Students worked in pairs to simulate the feeding behavior of birds and recorded their results. They also participated in a simulation set in the context of a drought on two islands in which only one food was available on each island. Although they did not have time to make sense of the collected data during that class period, Ms. Mitchell planned to have students analyze their data the following day to determine which beak would enable birds to survive.

Ms. Mitchell's current instruction reflects the aspects that initially drew her to CSiS. She now engages students in scientific inquiry based on the 5E model using CSiS-provided materials. Ms. Mitchell contrasted her instruction prior to CSiS with her current instruction:

> *[Before CSiS,] we did more stuff like reading out of the book, and just taking some notes, and taking a few quizzes, and a little bit of hands-on experiments, if we had the supplies, or the funds from the school to provide that opportunity. It was really hard to get hands-on things. It was more the old way of books, notes, and we tried to make it as fun as possible. As new ideas were shared with me, and new topics were presented, we started to stick those things in, and it just kind of has blossomed how we teach.*

Another important shift in her instruction is the use of CS, an approach she knew little about prior to hearing of Cohort 1's experience. When Ms. Mitchell engaged in CS data collection as a learner during Cohort 2's second CSiS summer institute, it furthered her interest and prepared her to engage students in the 8th grade pollinator project focused on bees and butterflies. As she said:

> *We actually went through it ourselves [in the summer institute]. We actually were out collecting bees and butterflies. Ben [the scientist] from the Midtown Zoo [our partner*

organization] was fabulous in getting us out into the fields, and I've really enjoyed it. By me enjoying it, it was able to transfer that over to the kids, because I had actually participated in it.... Overall, I think Ben really prepared us for that, that part of identifying and giving us the tools with those two sites. Then he also gave us cards that had pictures of the most common bees and butterflies that we would be finding in our area so kids could look at that.

Since she began implementing CS, Ms. Mitchell has devoted about a quarter of her instructional time to CS each school year. Ms. Mitchell finds it difficult to justify spending additional instructional time on CS because she perceives a misalignment between the pollinator-focused project and the state standards she is required to cover:

> *[The topic of] pollinators itself does not fit our curriculum. Collecting data and all that kind of stuff does, but [pollinators are] not really in our standards. We tried to tie it with genetics, and that kind of thing, a little bit. You need to be able to reproduce to keep your species alive. It was [stretching] a little bit with that. I know some of the other projects really did tie it in with the grade levels.*

In her first year implementing CS, Ms. Mitchell indicated that a majority of instructional time devoted to their project was spent collecting data. Although this proportion of time dropped slightly the following year, a considerable amount of CS instruction continued to be devoted to data collection. Unlike Ms. Simon's students, who were able to collect data on school grounds, Ms. Mitchell's students traveled to a local college campus to look for pollinators in a prairie with native plants. Ms. Mitchell sees value in CS as a means to increase student understanding of how to collect and make sense of data. Further, she sees CS as a means to authentically engage students in working with data and believes that students' CS experiences with collecting, analyzing, and reporting data will transfer well to other contexts, such as state-mandated tests. In her words:

> *One of the things that we also know is that on every one of these state tests, you have to look at data charts and you have to analyze data, so we really use that science inquiry part as the main thing.... We needed to get our science scores up. We were trying to figure out what we could do, common assessments and things like that. When CSiS came, the whole science inquiry, looking at data, analyzing data, doing charts and those kind of things evolved during it, so that also helped us, I believe, bring up our test scores. Over the past few years, we've made improvements on those. I think that it's played a big part.*

Although the pollinator project's misalignment with the state standards was problematic, she still thinks the experience has had an overall positive impact on students. In her words:

> *Even just in the symposium that we saw this year, the way the kids attacked it, the investigation that they did, and it was more led by them. I didn't feel like I had to spoon*

feed them through the process, and I think that's attributed to these kids who have had it for three or four years in 6th, 7th, and 8th grade—that they're investing because they see their work goes to a real scientist and can make a real impact.

During Ms. Mitchell's first year implementing CS, teachers in her school were organized into two teams per grade level, which facilitated scheduling off-site data collection. Having a team of teachers sharing one group of students resulted in minimal disruptions to others' course schedules. In contrast, during her second year implementing CS, there were no teams due to budget cuts and a reduced staff, which greatly complicated scheduling off-site data collection. However, the strong collaborative relationships that Ms. Mitchell fostered during the first year, both within her school and with teachers in the partner district, have been key in sustaining CS. Describing plans for working with teachers outside her school, she said:

I think we've built some relationships with teachers [in the other district]. I would not hesitate for a second contacting…some of the other teachers, and that might even be an opportunity where our students collect some data. They collect, and we swap data and analyze it, or something along that line. I think both schools would be very open to some sort of project like that, too.

Because of the challenges she faced during her first two years implementing CS, Ms. Mitchell hopes to make adjustments in future years. For example, she would like to establish an on-campus pollinator garden to increase student access and alleviate issues related to the time required and dependence on others to collect data. In her words:

The pollinator garden is still in its infancy and, hopefully, it'll all come to fruition here. That would be great because it's really just about a two-minute walk up behind the school. I could take my classes out every period, and we could look at data period by period by period.

Although she finds CS useful in increasing student interest and their ability to engage in authentic inquiry experiences, Ms. Mitchell remains concerned about the misalignment between the project and her state standards. However, she views collecting data to be relevant to the state standards she is responsible for teaching. It also seems Ms. Mitchell may feel most prepared to engage students in data collection, and she finds this aspect of the work motivating, both for her and students. Because student engagement influences Ms. Mitchell's decisions about what to include in her instruction, this will likely factor into which components of CS she emphasizes in the future. Conversely, her plans remain somewhat tentative due to new district-level administration and her uncertainty about the new superintendent's priorities. Thus, her control over the use of CS remains to be seen.

DISCUSSION

As described earlier, the case studies focused on teachers' intentions to sustain CS as an integral part of their science instruction. The following discussion is organized using the Theory of Planned Behavior ([TPB] Ajzen, 1991, 2012), a particularly prominent and comprehensive framework in social psychology for thinking about human decision making and behavior. The TPB holds that an individual's *Intention* is shaped by three types of beliefs: (1) *Behavioral Beliefs* (beliefs regarding the expected outcome of a behavior and subjective values about the outcome)*;* (2) *Normative Beliefs* (what one believes influential others will think if s/he exhibits the behavior, combined with the individual's motivation to comply with the influential others)*;* and (3) *Control Beliefs* (beliefs about an individual's ability to engage in behavior based on internal and external factors). Ajzen organizes these beliefs into three corresponding constructs: *Attitude Toward the Behavior*, *Subjective Norm*, and *Perceived Behavioral Control*.

Although our small, purposive sample limits the generalizability of the findings, the teachers' experiences provide guidance on how to support the successful implementation of effective school-based CS. Thus, it is important to consider implications for how to motivate teachers' intentions to implement school-based CS. It is often the case that teachers will choose only some components of an innovation to implement, while ignoring others; for example, collecting data as part of a CS project, but foregoing sense-making opportunities that help students' better understand the phenomena. In such cases, the TPB can provide insight into what components teachers choose to implement, and the factors that influence these decisions.

Each subsection below focuses on one of the three main constructs of Ajzen's TPB: *attitude toward the behavior, subjective norm, and perceived behavioral control*. Within each subsection, we first discuss various factors that have influenced teachers' implementation of school-based CS, and then propose how these findings can inform other school-based CS initiatives.

Attitude Toward CS

In examining the case study teachers' *attitudes* toward incorporating CS into instruction, the curriculum standards they are expected to teach play an important role, suggesting alignment with standards is a crucial consideration when aiming to foster positive *attitudes* toward a CS project. Because they are accountable for helping students achieve state standards, teachers said it was difficult to justify devoting instructional time to a project perceived to be only tangentially related to the standards they were expected to teach. In Ms. Simon's case, the pollinator project aligned well with 3rd grade standards, and professional development helped her understand how raising monarch butterflies, which she used previously to teach about insect life cycles (3rd grade content), could be expanded into a CS project. In contrast, Ms. Mitchell found the pollinator project misaligned with 8th grade state science content standards and could not justify spending a substantial amount of instructional time on CS activities. However, Ms. Mitchell recognized that CS implementation supported other instructional goals, such as addressing the science performance standards, as she found that having students reason about data in the context of CS strengthened their ability to collect, analyze, and report data in other contexts. She also believes CS increased student enthusiasm which may also account, in part, for her willingness to devote instructional time to it and her positive attitude toward implementing CS as part of science instruction.

These findings support those of others, including those of De Grove and colleagues (2012) in their study of teachers' intentions to use digital games in the classroom. When examining multiple factors, they found that "curriculum-relatedness" strongly influenced teachers' decision making about whether to include digital games in their instruction (De Grove et al., 2012, p. 2027). Similarly, Orlando's (2014) study of veteran teachers' use of technology also pointed to teachers' concerns that using technology meant deviating from content they are required to teach. De Grove et al. also associate curriculum-relatedness with teachers' ease of use, as alignment reduces the amount of time and effort required for determining how the innovation fits into the curriculum (2012).

In addition, it is important to consider existing initiatives that may be leveraged to support implementation. Teachers were more able to integrate their CS project with instruction when it was aligned with school district initiatives. For example, Ms. Simon described how implementing CS helped her fulfill her district's PBL requirement. By first introducing teachers to a more inquiry-based approach to instruction through kit-based instruction, CSiS was well positioned to incorporate CS, as it was a tool to help teachers further reform their instruction. Faced with limited instructional time, teachers view CS implementation more positively when it complements and builds on what they are doing in their classrooms. Therefore, one can foster positive *attitudes* toward CS by involving teachers in selecting projects to ensure alignment with their standards and with other instructional initiatives.

In their study of Western Australian classrooms, Dilkes, Cunningham, & Gray discuss "change fatigue," which they define "by its synonyms: being tired of change, adaptive failure, future shock and innovation fatigue," and identify it as a major factor affecting how teachers perceive reform initiatives (2014, p. 45). Orlando (2014) explained the danger of reform initiatives that lack teacher input, citing teachers' frustration that they are expected to enact plans in which they had no say, thus generating feelings of disempowerment. These feelings may be further exacerbated in veteran teachers who experience change fatigue as a result of expectations to frequently change their practices (Orlando, 2014). In a 2018 study of STEM education in the US, only a small proportion of K–12 science teachers indicated having strong control over determining their course goals and objectives, selecting instructional materials, and selecting content, topics, and skills to be taught (Banilower et al., 2018). Therefore, soliciting teacher input when selecting CS projects would likely be welcomed, especially at the elementary level, where about a third of science teachers reported having no control over such decisions (Banilower et al., 2018). In addition, engaging teachers in this process could provide opportunities to identify existing initiatives to leverage. These approaches help bolster teacher buy-in and enable them to see how CS can complement and enhance, rather than supplant, what they are already doing in the classroom.

Subjective Norm

Both cases demonstrate how a positive *subjective norm*, in the form of others' support, helps to build momentum in school-based CS implementation. Having a network of teachers implementing CS has many benefits, including opportunities for troubleshooting, encouraging one another, and sharing of supplies and data. Given the close-knit relationships between each teacher and their respective colleagues, it was important to them that these other teachers were on board.

Both Ms. Simon and Ms. Mitchell spoke optimistically about future plans for CS, mentioning involvement of other teachers in their school. For example, Ms. Simon predicted that once she and her colleagues join other 3rd grade teachers at a larger school, their enthusiasm for the pollinator project will be contagious and other teachers will want to join. Ms. Simon is also interested in helping other teachers get started by providing them with caterpillars. Ms. Mitchell expressed interest in continued cross-district collaboration that would help teachers to share collected data for their CS project. Therefore, it seems that CS projects contain an inherent social component that is likely to draw teachers in.

These findings support others' research that has indicated how collegial support plays an important role in making an innovation a routine part of teachers' practice. In addition, because any instructional innovation can present stress-inducing challenges unique to the initiative, it is important to consider how to foster an environment of peer collaboration. For example, Dresner and Worley found that "collegiality provided [teachers with] confidence to use more innovative teaching techniques; practical opportunities to exchange workable ideas, solutions, and resources; and a sense of being part of a larger movement" (2006:10). Related to an earlier point, Dilkes, Cunningham, and Gray (2014) found that collegiality can help teachers cope with feelings of change fatigue triggered by curriculum reform. Touching on a broader benefit, others found that collegial support may help alleviate professional isolation, which has been found to correlate with occupational stress in teachers (Dussault et al., 1999). Therefore, individuals orchestrating school-based CS projects may want to coordinate networks of teachers to create a positive *subjective norm* toward CS and provide a sustainable support system for participating teachers.

In the cases of Ms. Simon and Ms. Mitchell, school administrator opinions did not appear to have a particularly strong influence on their use of CS. CSiS provided opportunities for administrators to engage in the program, and it communicated to administrators the merits of CS. Administrators viewed CS favorably to the extent that it aligned, or at least did not conflict, with school- or district-level initiatives. Therefore, involving administrators early in CS project implementation may help foster a positive subjective norm toward CS schoolwide.

Perceived Behavioral Control

Perceived behavioral control includes internal and external components, both of which were present in the cases. The cases demonstrate how self-efficacy (Bandura, 1997), an internal component, plays an important role in the likelihood that they will implement CS. In CSiS, professional scientists with in-depth expertise were a powerful resource for familiarizing teachers with CS projects and increasing teachers' confidence. Ms. Mitchell described how having the scientist lead her in project activities as her students would experience (e.g., collecting and entering data) helped her to feel more confident to, in turn, engage students. Ms. Simon indicated strong positive perceptions of behavioral control, indicating that she and her colleagues considered the scientists to be more of a "guide on the side."

Others have also emphasized the benefits of scientist partnerships and engaging teachers directly in field work as a means of bolstering teacher confidence (Dresner & Worley, 2006). Similarly, as Powell-Moman and Brown-Schild (2011) suggest in their investigation of professional development, impacts that increase novice teachers' self-efficacy encourage more frequent use of inquiry-guided instruction.

Considering external factors, it appears crucial that data collection sites are easily accessible, ideally on school grounds. Ms. Simon recognized how having an on-site pollinator garden at her initial school site facilitated data collection. Off-site data collection requires funding for transportation and a substantial amount of instructional time. In Ms. Mitchell's case, off-site data collection also required other teachers to change their schedules, resulting in disrupted instruction in other content areas. When data collection can take place on school grounds, these challenges can be avoided, and data collection can then be done in as little as one class period, and students can collect data much more frequently.

Accounting for both internal and external factors, it is essential to create conditions that increase teachers' perceptions of behavioral control, or self-efficacy. For example, selecting a project that allows students and teachers to conveniently collect data on school grounds eliminates dependencies on obtaining funding and permissions for transportation, as well as concerns about loss of instructional time. Further, to help teachers feel adequately prepared and confident carrying out a CS project with their students, local science professionals can assist when possible (e.g., engaging teachers as learners, providing ongoing support). Although teachers may rely on these professionals to varying degrees as they integrate CS into their instruction, having individuals with expertise in the project's focus area is an asset.

CONCLUSION

CS has the potential to transform science instruction, providing students with opportunities to engage authentically in science practices, something that is currently uncommon in K–12 classrooms across the United States (Banilower et al., 2018). Our research suggests multiple ways that individuals involved in designing and supporting use of CS projects can increase the likelihood of school-based CS reaching its transformative potential. In the early phases of project design or selection, it is important to seek teacher input to ensure that the CS project aligns with (1) the standards that teachers are expected to teach, (2) ongoing school district initiatives, and (3) school administrator expectations. Professional scientist support is also crucial to provide initial support and expertise as teachers and students become familiar with the CS project's technical aspects and scientific goals. Case study data also suggest that teachers implementing CS projects benefit from ongoing opportunities to network with other teachers, particularly peers who they can go to for support and troubleshooting. To the extent possible, on-site data collection facilitates implementation by enabling more frequent data collection and removing the barriers of transportation and extended time away from the classroom. Taking these conditions into account when planning for the use of CS in formal education settings increases the likelihood that teachers will implement the projects in ways that meaningfully engage students.

Acknowledgement
This research was supported by National Science Foundation Grant DRL - 1238136. Any opinions, findings, and conclusions or recommendations expressed in this article are those of the authors and do not necessarily reflect the views of the National Science Foundation.

REFERENCES

Ajzen, I. (1991). The theory of planned behavior. *Organizational Behavior and Human Decision Processes*, *50*(2), 179–211.

Ajzen, I. (2012). The theory of planned behavior. In W. Kruglanski & E. T. Higgins (Eds.), *Handbook of theories of social psychology: Vol. 1* (Vol. 1, pp. 438–459). Sage.

Astin, A. W., Vogelgesang, L. J., Ikeda, E. K., & Yee, J. A. (2000). *How Service Learning Affects Students*.

Bandura, A. (1997). *Self-efficacy: The exercise of control.* W.H. Freeman.

Banilower, E. R., Smith, P. S., Malzahn, K. A., Plumley, C. L., Gordon, E. M., & Hayes, M. L. (2018). *Report of the 2018 NSSME+*. Horizon Research, Inc.

Bybee, R. W., Taylor, J. A., Gardner, A., Van, P., Scotter, J. C. P., Westbrook, A., Landes, N., Spiegel, S., Stuhlsatz, M. M., & Ellis, A. (2006). *The BSCS 5E Instructional Model: Origins and Effectiveness*.

De Grove, F., Bourgonjon, J., & Van Looy, J. (2012). Digital games in the classroom? A contextual approach to teachers' adoption intention of digital games in formal education. *Computers in Human Behavior*, *28*, 2023–2033.

Dilkes, J., Cunningham, C., & Gray, J. (2014). The New Australian Curriculum, Teachers and Change Fatigue. *Australian Journal of Teacher Education*, *39*(11), n11.

Dresner, M., & Worley, E. (2006). Teacher Research Experiences, Partnerships with Scientists, and Teacher Networks Sustaining Factors from Professional Development. *Journal of Science Teacher Education*, *17*(1), 1–14.

Dussault, M., Deaudelin, C., Royer, N., & Loiselle, J. (1999). Professional isolation and occupational stress in teachers. *Psychological Reports*, *84*(3 Pt 1), 943.

Lee, C. D. (2003). Committee on Increasing High School Students' Engagement and Motivation to Learn: Fostering High School Students' Motivation to Learn. In *Engaging Schools: Fostering High School Students' Motivation to Learn*. The National Academies Press.

Lincoln, Y. S., & Guba, E. G. (1985). *Naturalistic Inquiry* (1st edition). SAGE Publications.

National Academies of Sciences, Engineering, and Medicine. (2018). *Learning Through Citizen Science: Enhancing Opportunities by Design*. The National Academies Press. https://doi.org/10.17226/25183

NGSS Lead States. (2013). *Next generation science standards: For states, by states.* The National Academies Press.

NSTA. (2018, October). Engaging Students Through Citizen Science. *NSTA Reports*, 17.

Orlando, J. (2014). Veteran Teachers and Technology: Change Fatigue and Knowledge Insecurity Influence Practice. *Teachers and Teaching: Theory and Practice*, *20*(4), 427–439.

Powell-Moman, A. D., & Brown-Schild, V. B. (2011). The Influence of a Two-Year Professional Development Institute on Teacher Self-Efficacy and Use of Inquiry-Based Instruction. *Science Educator*, *20*(2), 47–53.

Yin, R. K. (2003). *Case study research: Design and methods*. Sage Publications.