Teachers' Fostering of Real Work with Real Consequences through School-based Citizen Science

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Abstract: Students need learning experiences that build capacities to agentively engage with issues challenging our world today. Teachers are often under-supported in endeavors to facilitate such learning experiences. Grounded in principles of consequential learning and expansive framing, this design-based research study sought to better understand the ways in which STEM teachers support students' real work in the world as members of a school-based citizen science lab. Qualitative analysis of transcripts from teachers' post-professional development and post-enactment interviews was used to characterize the ways teachers frame roles, goals, and community relationships intended to support students' real work with real consequences. Findings illuminate ways teachers foster consequential STEM learning and suggest design principles for supporting teachers' ongoing learning for and facilitation of real work with real consequences.

Introduction

To face the existential challenges to life on a planet that is rapidly changing, increasingly interconnected, and systemically entangled, today's young learners need educational experiences that prepare them to become knowledgeable, engaged agents of change toward a more just and sustainable world (Jongewaard et al., 2023). To this end, it is important that students gain knowledge about complex global and local issues and that they are able to connect in-school learning with relevant uses in contexts that matter to them (Barab et al., 2019). Youth are able to deal with more complex socio-scientific issues than thought in the past (Windschitl & Calabrese Barton, 2016; see, for instance, Barab et al., 2006; Jordan et al., 2021). Youth have the desire and capacity to participate as knowledgeable contributors to communities within and beyond school walls; they are able and willing to engage in real work with real consequences and need adults who will support them in doing so (Jordan et al., 2021; Trott & Weinberg, 2020). Teachers are well-positioned to be such adults, but have limited opportunities and support for learning about and enacting pedagogies to facilitate this type of student learning and engagement. Best practices for teacher professional development (PD) suggest that teachers need opportunities to practice the sorts of authentic learning that they wish to enact with their students (Southerland, 2016).

Promising approaches to providing such authentic learning opportunities for teachers come in the form of Research Experience for Teachers programs (RETs) (Southerland, 2016) as well as engagement with school-based citizen science (CitSci) (Roche et al., 2020). The context for the current project was unique in combining the RET model with a school-based CitSci project to engage teachers in expansive framing of students' school-based science learning. Thus, it offered an opportunity to bridge design principles derived from these two literatures. Together, RET and CitSci provide opportunities for (a) engaging in authentic scientific processes and practices and (b) connecting with related organizations in the world outside of school that they can then introduce to their students. Such programs foster content knowledge but also visibility and meaningfulness for students (e.g., Harris et al., 2019) and teachers as contributors to larger communities working to transform complex socio-scientific systems in the service of more just and sustainable futures. Moreover, when reflecting on practice, as well as when planning for future enactment, how teachers frame what they are doing impacts what they envision as possible and what they strive to do with their students (Horn, 2010). Thus, in this study we sought to understand how teachers view their practices and their successes and challenges in these efforts subsequent to their participation in the first iteration of the RET program. Our aim was to derive insights for improving subsequent cycles of DBR aimed at helping teachers develop their capacity to support students' real work with real consequences through CitSci.

Theoretical frameworks

Built on the productive disciplinary engagement framework (Engle & Conant, 2002) and connective and consequential learning (Agarwal & Sengupta-Irving, 2019), the design principle of inviting youth to engage in *real work with real consequences* posits that students are entitled and expected to participate in disciplinary endeavors that are consequential to youth and their communities. Research suggests that engaging students in real work requires that teachers support youth in *expansively framing* (Engle et al., 2012; Jongewaard & Jordan, 2022) their learning as relevant and useful to themselves and others across time in a variety of communities outside the classroom (e.g., neighborhoods and disciplinary communities). Teachers, as well, benefit from professional opportunities that help them expansively frame their own pedagogical practices (Benichou et al., 2022). Our stance is that, as with youth, when teachers frame the work they and their students do as being useful and meaningful across a variety of people, places, times, topics, and roles, that is, when they frame their practices expansively, then they are more likely to endeavor to engage students in real work with real consequences.

Teachers' expansive framing may occur in various ways. Here, we focus on expansive framing of learning goals, participant roles, and community. In a previous study, Jongewaard and colleagues (2023) characterized school-based CitSci as expansively framed insofar as learning goals, participant roles, and community are conceived of respectively as (a) student-led inquiry in real-world science practices where (b) students are intellectual leaders, decision-makers and agentive contributors, whose work is (c) relevant to communities beyond the classroom. Learning to expansively frame pedagogical practices in the service of real work with real consequences requires teachers to take perspectives different from those often privileged in their education courses and from those typically encouraged by local and broader systemic requirements, particularly in regards to goals, roles, and community. For instance, teachers tend to be pulled towards pedagogical strategies that narrow goals for student learning to progress as measured through standardized assessments. Expansive framing of learning goals makes room for transformative possibilities that include students' capacities for taking action in and with their own communities. Furthering such capacities demands that teachers expansively frame students' roles in the classroom—and even in the larger community—beyond that of *learner* to include *contributor*. Expansively framing learning as real work with real consequences includes expanding views of *community* as not only audiences of students' disciplinary authority but as partners and beneficiaries of students' disciplinary engagement (Jordan et al., 2021).

Methods

We report on analysis of data from the first cycle of a three-year, design-based research study (McKenney & Reeves, 2018) that draws on theories of expansive framing to support teachers in learning about and facilitating real work with real consequences through citizen science. The following question guided the current study: *What are the varied ways teachers frame community, roles, and learning goals in their enactment of agrivoltaics citizen science (agriPV CitSci) following participation in an RET designed to foster real work with real consequences?*

Ten teachers participated in the first iteration of a six-week RET in which they worked alongside agriPV scientists, engineers, and learning scientists to participate in and develop plans for supporting their students in agriPV CitSci. AgriPV is a novel approach to growing food and producing energy through synergies created between solar panels and plants. Because this engineering innovation is in early stages, K-12 students can make valuable contributions by collecting, analyzing, and sharing data from school gardens (Jongewaard et al., 2023). They can also contribute to communities on multiple scales as they determine uses for the food and energy produced and engage with the complex intersections of science, socio-technological advances, sustainability, and community needs. Foci of the RET program included developing socio-technological understanding of agriPV, engaging in authentic scientific practices through data collection, analysis, and interpretation, and planning for enactment of agriPV CitSci with their students using a real work with real consequences framework.

Commencing with their participation in the RET, teachers joined a networked lab of researchers, school sites, and community partners distributed across an arid desert region of the U.S. Study findings were derived based on analysis of data from all ten teacher-participants in the first year of the lab's RET. However, here we limit ourselves to describing two illustrative cases, drawing examples from two teachers chosen because of their high level of implementation, their taking up of pedagogies promoted by the RET, and their different classroom contexts (one was a middle school STEM teacher and the other a high school Environmental Chemistry teacher). Val had over 20 years of K-8 teaching experience and two years teaching agriPV in her STEM classes. Liz had over 10 years of experience teaching high school science. The RET was her first encounter with agriPV CitSci.

We sought to understand the range of ways agriPV CitSci enactments occurred in terms of what the teachers said about community, roles, and goals. Semi-structured interviews were conducted at the end of the RET and again at the end of the first school year of teachers' involvement in the program. Interviews were designed to evoke reflective stories about teacher learning and projective stories related to challenges, successes, and pedagogical practices. Stories, especially those elicited in interviews, usually include a who, what, when, where, and why alongside evaluations that reveal tellers' stances on situations, actors, and resolutions (Labov, 2006). Thus, by asking for stories, we were able to surface ways teachers defined the problems of agriPV CitSci, who they saw as the more or less authoritative and responsible actors, what places teachers saw as relevant to their agriPV CitSci work, what actions people took with whom, and what values they attached to the different events and outcomes. These elements are the focus of expansive framing. Better understanding teachers' views on these elements allowed us to consider whether and how they were framing their practice as being limited to traditional classroom spaces with traditional roles and learning goals or if they framed more expansively, linking their practice to settings beyond the classroom and aligning students with roles as contributors to real work.

Members of the research team deductively coded interview transcripts (Miles et al., 2014) to identify all instances of teachers' talk about community, roles, and learning goals. We further interrogated the coded data, writing interpretive memos, identifying patterns, clustering, collapsing, and testing tentative initial themes (Braun & Clark, 2006) characterizing teachers' framing of these elements in relation to their CitSci enactment. As we iteratively interacted with the data, we developed subcodes such as, in relation to community, "partners within school" and "partners outside of school." We used a previously developed framework (Jongewaard & Jordan, 2023) to characterize teachers' framing as *narrow* in terms of goals, roles, and community or as *expansive*. Throughout our analytic process, team members alternated between independently interpreting the data and collectively negotiating interpretations to characterize the various ways agriPV CitSci was framed and enacted.

Findings

Our findings show that there are many ways to expansively frame learning in terms of community, student roles, and learning goals. The variety of ways conduce to different forms of engagement in and beyond learning contexts and to different instantiations of real work with real consequences. In this section, we share interpretations of two teachers' framing of agriPV CitSci in their practices.

Val's framing of community stretched from members of the school community (e.g., younger students, maintenance staff), to people and organizations outside of the school (e.g., families, a local farm, researchers, other schools' agriPV sites). Her framing of community was closely tied to her framing of learning goals and student roles and to how she sought to frame these for students.

Val's story of partnering with a family-run organic farm illustrates the ways she united these three aspects in her expansive framing of student learning. Val emphasized to her students that the farm owners and outreach coordinator were community collaborators participating in a mutually beneficial partnership in which the students' roles included them actively, *"reaching out to [the partner] farm and constructing the letters to keep the partnership…going."* The farmers gave students planting advice and challenged students to devise ways to make farming more cost effective. As the students worked on this challenge throughout the year in their agriPV gardens, they achieved both predefined learning goals such as systematically collecting and making sense of data and evolving student-driven learning goals such as testing conjectures about effective irrigation methods. In these processes, students also achieved Val's goals that they become problem-solvers who *"owned"* their work as a *"community project"* that left a legacy for the school. The farm partners benefited from the students' real work (e.g., they requested that students study possibilities for alfalfa composting as fertilizer). Val's narrative shows how she framed the project expansively in terms of a community partnership in which students were responsible decision-makers who were learning science through authentic problems: *I was like, 'Oh, we've got this other compost experiment. . . and we need to make sure we're following up and following through on our end of the partnership. So, what kind of suggestions do you guys have for that? How do we want to get that moving forward?'* Val reported that a group of students designed experiments and sent their results to the farm, their principal, and researchers, thus expanding community connections even beyond the class-farm partnership.

Liz's framing of community in her practice was expansive in that she saw the potential for many cross-disciplinary partnerships within the school. An important role for her as the teacher was *"getting some buy-in from . . . many people initially."* With visions of particular ways partnering could help her classes and other classes achieve their disciplinary learning goals, she sought connections with the ceramic teacher to have students make art for the garden, with the culinary class to cook harvested food, and with physics teachers whose work with voltage and current would tie in with solar energy production. Liz recruited a math class to calculate the amount of soil the garden needed. Liz's framing of learning goals included general skills such as *"think[ing] outside the box."* It also included deep disciplinary learning such as analyzing and interpreting data such that students could, "*make connections between what they did and what that means and how [that applies] outside the classroom*." Her framing of student roles primarily focused on their activities within class: she positioned them as group leaders who organized daily tasks and took up roles as teachers to each other and to Liz, for instance, when more knowledgeable students taught others how to use the tools necessary to build garden beds and irrigation systems.

Through the illustrative examples of these two teachers, we can see that teachers can expansively frame *community* as branching out beyond the school as well as reaching deep within a school. *Learning goals* can be expansive in terms of how much they move beyond required curricular standards as well as how interwoven they become with standards across disciplines. *Student roles* can be framed expansively both in who determines and pushes forward projects and in the ways in which pre-determined projects are enacted.

Both Val and Liz articulated challenges they had in terms of enacting their initial visions of agriPV CitSci. Generalizing across their stories, we saw themes related to the challenges of partnering with community members; it was difficult to get busy, potential partners to see how collaboration with students could be mutually beneficial, rather than students being seen as "*just kids*," a view Val suspected some of their partners had. If student contributions are not seen by community members as worth the effort it takes to maintain partnerships, then framing of student roles that relies on students as leaders in those contexts becomes difficult to actualize. If students are "*not used to being given any agency whatsoever*," as Liz asserted, then helping them assume decision-making roles will take "*longer than it should.*" It also takes time, confidence, and experience for teachers to redesign their curricula to move toward student-driven inquiry away from, as Liz said of her own previous curriculum, "*cookbook chemistry*." By the end of the year, Liz felt that the changes she had made throughout the year gave her *"a lot more confidence that students can do this and can lead.*"

Significance

Findings from this study contribute to understanding ways real work with real consequences can be enacted and supported in STEM learning contexts. Future design cycles with new teachers will enlist the following tentative principles inspired by this study to engage teachers in envisioning expansive possibilities for their own practices: a) *help teachers design strategies for developing partnerships that occur both broadly, outside the school, and deeply, within the school and b) create opportunities for teachers to share stories that model the range of ways real work with real consequences can be envisioned and enacted*.

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