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Studying K-12 and post-secondary teachers' reflections on the value of a citizen science project for fostering learning: The case of a winter stream project

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ABSTRACT

Citizen science programs offer the public opportunities to be involved in hands-on scientific data collection and study. Despite a history of incorporating citizen science in the K-12 classroom, little research has focused on projects that are appealing to both K-12 instructors and higher education faculty. Our study investigates initial barriers and motivations for participation in citizen science at multiple education levels using a winter, stream ecology citizen science project. Our findings indicate a growing interest in citizen science programs in winter, as they provide opportunities for collaboration, encourage flexible data collection, and offer tangible results for participants to reflect on their local ecological habitats.

Keywords: citizen science, higher education, outreach, K-12, science education

INTRODUCTION

Water is an essential resource for life, and with climate change, many freshwater resources will be threatened especially in areas with lower economic development and adaptive strategies for climate warming (Koutroulis et al., 2019). Additionally, studies on winter stream ecology are rare and new investigations indicate a need for broadening research on climate impacts to winter-active and cold-adapted aquatic insects (Anderson et al., 2022; Bodmer et al., 2023; Nyquist et al., 2021). Despite harsh winter conditions, there are insects, which are adapted to complete the adult stage of their life cycle during this season, including a family of aquatic flies called midges, in the chironomidae family (Ferrington Jr & Berg, 2019). Previous studies have revealed natural history and biological information about these insects (Bodmer & Nyquist, 2022; Bouchard & Ferrington, 2009; Giłka et al., 2013; Soszyńska-Maj et al., 2016); however, climate change impacts provide a new investigative angle (Bodmer et al., 2023). Studies of some stream environments are possible during the winter season due to the buffering effects of ground water, which can keep these streams open and not frozen year-round (Krider et al., 2013; Nyquist et al., 2020). The growing need for research on winter stream ecology provides an opportunity for public engagement and education. Empowering communities to engage in monitoring and collecting scientific data on local freshwater resources contributes to scientific literacy, social participation in natural resources management, and improvement of ecosystem services (França et al., 2019). Freshwater scientists have a growing interest in involving the public in aquatic research yet barriers to implementation remain (Hopfensperger et al., 2021).

Citizen science can be broadly defined as the involvement of volunteers in research (Dickinson et al., 2010; Silvertown, 2009) who, specifically, may collect or analyze data (Silvertown, 2009). There is a growing appreciation for citizen science as a research, educational, and community building tool (Haywood et al., 2016; Paige et al., 2015; Tyson, 2019). Its growing popularity can be traced to increased access to technological advances that make data collection easier and more accessible and to growing public environmental concerns (Gal, 2019; Tyson, 2019; Vance-Chalcraft et al., 2022). Citizen science participation has also been linked to a greater sense of wellbeing in participants and empowerment around local environmental issues (Bonney et al., 2016) in addition to fostering a sense of place and community (Haywood et al., 2016). With growing public environmental concerns, there is a need for opportunities to increase self-efficacy and community resilience through shared pro environmental activities (Ojala et al., 2021). One way to increase public involvement in conservation and resource management is to expand opportunities for participation in citizen science efforts, including opportunities for students and teachers from diverse educational institutions and levels. Given classroom demands, we must understand how to lower barriers, decrease challenges, and improve the impact of these experiences. We use a winter stream ecology citizen science project focused on aquatic insects to explore the usability and utility of a citizen science project integrated into K-12, undergraduate, and associate-level programs.

Volunteers for this particular citizen science project document the winter activity of aquatic insects like stoneflies, mayflies, caddisflies, and non-biting midges by walking transect lines near snow-covered stream banks. Participants also upload pictures and share observations about the weather, location, habitat, and stream conditions. Data is uploaded and accessed using the ancedata app, an online and open community platform for managing community science data. The project provides university researchers and public audiences with insights about winter-active aquatic insects, which are a vital food source for trout, and open datasets that can be used to better understand the biology of winter-active insects, to explore potential effects of climate change, and to inform the management of streams in the wintertime.

LITERATURE REVIEW

Most programs involving citizen science are focused on gathering environmental and ecological data on habitat health and species distribution or abundance on the landscape (Roy et al., 2012). Thus, in addition to scientific and monitoring benefits, citizen science programs have been found to be effective avenues for environmental education in various settings (He & Wiggins, 2017). The experiential and hands-on learning provided through citizen science programs has been found to produce an effective informal learning environment for participants (Kelling et al., 2015; Masters et al., 2016) and to foster a greater understanding of scientific processes and tools (Bonney et al., 2016; Gal, 2019). The degree of learning and scientific literacy gained, however, is linked to the degree of involvement in diverse aspects of the scientific process (Koomen et al., 2018; Shirk et al., 2012) and to increased participation in the program from contributory to collaborative to co-creative levels (Bonney et al., 2009). More recently, citizen science projects have been implemented and studied within formal (e.g., school) and non-formal (e.g., museum) learning settings (He & Wiggins, 2017), where individuals participate in semi-structured learning (Eshach, 2007; He & Wiggins, 2017). Although implementing citizen science programs in the classroom may not result in as much intentional teacher professional development or scientific mentoring of students, many similar benefits have been attributed to citizen science participation in formal settings (Gal, 2019; Paige et al., 2015; Chen & Cowie, 2013).

Case studies and investigations of citizen science programs within different educational contexts are limited, however, and have only recently received more attention (e.g., He & Wiggins, 2017; Paige et al., 2012). Most of these focus on primary education settings (Chen & Cowie, 2013; Paige et al., 2012, 2015; Trautmann et al., 2012; Tsivitanidou & Ioannou, 2020; Zeegers et al., 2012), with a limited number of outlining benefits to post-secondary education (Vance-Chalcraft et al., 2022; Wyler & Haklay, 2018). Investigations in post-secondary settings have focused primarily on research centered institutions (R1 in the Carnegie classification system) with little focus on teaching focused or two-year institutions (Vance-Chalcraft et al., 2022). Additionally, little work has investigated the features that make citizen science programs attractive to both primary and post-secondary teaching institutions. An ever-present challenge emerging from the incorporation of citizen science programs is the need to meet both teaching standards and scientific goals (He & Wiggins, 2017; Zoellick et al., 2012). There is some evidence that involving educators during the early stages of a project may result in increased adoption and follow-through (He & Wiggins, 2017); however, there have been no investigations of this involvement across primary, secondary, and post-secondary institutions. Additionally, there remains a lack of investigation into barriers across primary and post-secondary education settings with a focus on non-R1 institutions.

Our project bridges some of these gaps by investigating the initial hesitations, needs, desires, and motivations of educators across primary, secondary, and post-secondary settings, including BA/BS and associate degree granting institutions, which have not been an exclusive focus in literature. By involving educators early in the process of implementation and exploring their initial reactions to a program, this project offers important insights that can help with strategic program design and targeting. As Davis et al. (2019) points out, one of the key challenges for citizen science is to attract engagement and turn it into participation.

Purpose & Research Questions

The purpose of this study is to investigate initial barriers to participation and motivations around involvement in citizen science by teachers and faculty. The main questions guiding this research include:

1. What initial hesitations and needs do faculty and teachers have which guide their decision making around citizen science participation?
2. What motivations do teachers and faculty have for participating in citizen science or getting their classrooms involved? What benefits or experiences do teachers and faculty desire to gain?
3. What characteristics, ascribed by the participants, can make citizen science project participation intensive and learning centered?

METHODS

This project explored perceptions around citizen science involvement and, thus, utilized a qualitative research approach as defined by Creswell and Creswell (2018); namely, an exploration of the meaning individuals or groups attribute or associate with experiences and problems. Like Phillips et al.'s (2019) interview work on engagement in citizen science, we used situated learning theory as a lens to examine how to best support content learning, manage context, and improve the potential engagement of teacher and student communities in authentic settings. Our work is especially focused on the experiences, perceptions, and motivations of faculty and teachers from institutions largely overlooked with citizen science involvement. We are also interested in the challenges faced by these volunteers during the initial stages of a citizen science program launch.

We conducted semi-structured, online interviews over the Zoom™ platform with 11 individuals who worked as instructors at one of three different teaching institutions, e.g., K-12 schools, two-year colleges, or four-year colleges. Participants were invited into the study based on their stated interest in our citizen science program and/or involvement with our previous outreach events. We obtained Institutional Review Board approval before initiating recruitment, and we followed best practices (Dillman et al., 2014) for all portions of the study involving human subjects (e.g., recruitment, informed consent, interviewing, and data management). After reaching out to 35 potential participants, we successfully completed interviews with three K-12 teachers, three faculty from two-year technical colleges, and five faculty from four-year teaching colleges from the Midwest region of the United States. Our number of interviews were low compared to the number of educators we contacted, likely due to the busy schedules and lack of extra time for many educators in the USA. However, some educators we contacted also informed us that our project did not fit into their teaching schedule in that given year or that they were on temporary leave. All interviewees were science teachers or instructors either in K-12 or higher education settings. Their educational and professional backgrounds were in STEM and many of them had ecological training and taught courses related to the environment. Most interviewees had some experience with citizen science either in the classroom or in their personal lives; but three interviewees had limited experience with citizen science in classroom. Years of teaching experience for all the interviewees ranged between one to 30 years, with an average years of experience for the sample studied to be 17.

After sharing a description and overview of a potential citizen science protocol focused on winter stream ecology and aquatic insects, we used an interview guide to explore initial hesitations, challenges, needs, resources, expected benefits, and motivations. Following situated learning theory (Lave & Wenger, 1991), we approached our data collection and data analysis work in the context of citizen science as a potential learning environment for classroom communities to explore science practice, identities, knowledge application, and use of tools or protocols in an authentic, but low-risk setting. We focused on how to support the social and physical learning context, content learning, and participation of teachers and student groups. More specifically, our interview guide consisted of 16 main questions with 11 secondary, probing questions. The main questions fell into eight categories:

(1) general background on teaching and education,
(2) experience with citizen science,
(3) hesitations around implementing a new citizen science project,
(4) needs,
(5) motivations,
(6) perceived challenges with implementation,
(7) potential benefits to instructors, the program and students, and
(8) recommendations for designing future programs.

We followed the interview guide but also probed interviewees further as new themes emerged following a semi-structured format (Berg & Lune, 2011). Participants were contacted by email and interviews were conducted in various months spread over the 2023 calendar year. Interviews were recorded and transcribed with interviewees' full consent.

We analyzed the data by reviewing it three times between two researchers allowing for multiple comparisons of emerging themes and patterns in an open coding technique (Esterberg, 2002; Strauss & Corbin, 1998). Both researchers involved in the analysis have qualitative and quantitative research backgrounds and PhDs in ecology and communication, respectively. Following best practices for open coding (Esterberg, 2002; Strauss & Corbin, 1998), we reviewed transcripts separately, sorting them into themes, and then compared notes to check that both researchers had detected the same themes. Any discrepancies were addressed by revisiting original transcripts. The transcript analysis helped categorize insights, which are presented below.

RESULTS

Hesitations That Guide Initial Decision-Making Around Citizen Science

Access to natural environment

A significant hesitation that surfaced in 73% of participant interviews was access to the natural environment or a field site in order to gather data. Logistics, costs, and liabilities connected to transportation was often one of the first challenges mentioned during interviews. If the natural environment could not be accessed, instructors would need a way to re-create a natural space in their school communities and protect or manage it.

Faculty were hesitant to identify a local, relevant site with the right type of stream (i.e., streams with open water and insects), especially in urban settings, or obtaining enough geographic variability that would produce relevant data.

Due to the winter focus, interviewees also mentioned changing weather conditions (e.g., snow on ground), stream conditions, and feasibility of field outings as anticipated challenges. As one interviewee said,

> "Are [students] up for going into the field? Can we do so realistically in the winter season, given that labs are only usually one day a week and weather plays in, is it feasible or not?" (4-4yr)[1].

One K-12 teacher responded,

[1] Quotes are attributed using an interviewee number and indicating the interviewee's type of educational institution.

> "The biggest thing for me would be what time of year is ideal for the sampling, and maybe some help locating some sites that we could get to from campus, because the idea taking a field trip, where we're like getting on a bus or driving is it probably impossible; we need a walkable site" (3-K12).

Safety & risk

Protecting student safety, especially when snow, water, and ice are present, was another hesitation mentioned by 45% of interviewees. K-12 instructors shared general concerns about emergencies, liability, and adequate supervision of large groups. One K-12 instructor shared:

> "You gotta have two adults to be able to walk the students somewhere and be safe in case there is an emergency" (1-K12).

College instructors focused more on making sure students could access public versus private property and ensuring that undergraduates stayed in small groups for safety and accountability.

Extent of knowledge & time commitment

36% of interviewees shared concerns about being able to scale up or scale down citizen science project requirements for data collection, depending on the time and expertise of the class. As one interviewee mentioned,

> "An undergraduate student with entomology or freshwater biology experience would come to this project at a different place than a high school group that was taken out on a class field trip" (2-4yr).

Other interviewees were concerned about how many data points or collection times students were required to complete, as integrating a project that requires multiple field visits might be too extensive of a time commitment. As one interviewee said,

> "My hesitancy is that there's easily collectible data, or it does not require investing multiple class periods to get some data" (8-2yr).

Other concerns centered around ease of data processing, since many instructors had limited time with students during lab, and general concerns on data quality.

Clear & relevant objectives & audiences

36% of interviewees wanted to be sure the scientific questions, objectives, and topics were compelling for their students and geographic area. They wanted access to clear outcomes and guidelines for their classroom sessions and to be able to demonstrate the usefulness of the data with students. They also added,

> "the kids do not want to be tricked into collecting data that has no purpose" (3-K12).

Another interviewee added,

> "the question and the topic should be relevant for the area. My students do want to find out about things that live in streams in [our specific region], as opposed to just [collecting data] for its own sake" (2-4yr).

Equity

There was concern about equity for 45% of participants, especially surrounding transportation and classroom time to complete field sessions, as not all students had access to transportation to streams. Students also had varying levels of mobility to get to streams and walk around in the field. One college instructor reflected on access and mobility needs by considering site characteristics by

> "choosing the sites carefully along the river ... places that are easy to walk, and not ... a huge slope down to the bank" (9-4yr).

This made some interviewees hesitant to integrate this project as a required component or even as extra credit in their curriculum. Even quality winter gear was a concern for both K-12 and higher education faculty, as one interviewee said,

> "something like 70% of our students are on the low end of the socioeconomic scale, so we have to make sure that they do have quality mittens and shoes. I will not let them come out if they do not on a cold day" (7-2yr).

Results

Hesitations around the quality of results were expressed by 73% of participants. Interviewees were hesitant to join projects that would not yield interesting, compelling, and active results, as it was important that students could get engaged and excited during field sessions. As one interviewee said,

> "it is one of those frustrating things with science, where you're really trying to get an image of what reality is which can conflict with the desire to give students an experience, where they're collecting non null data. As a scientist, null data is great. It's something that you need, those zeros, but I think, the difficult part of citizen science is trying to give [students] the experience of getting positive detections, while also collecting the data accurately. And that's especially a tough thing about winter ecology and collecting stuff in winter; there's just so much less activity out there" (6-4yr).

Lack of obtaining interesting results was also a concern for providing students with robust analysis opportunities, and so instructors wanted to figure out alternatives. Another challenge brought up by some interviewees was that there may be difficulty in maintaining a strong interest in insects over time since these are not very charismatic organisms. As one K-12 teacher said,

> "People in general do not really care about insects, but I think anyone, if you brought them in to do a macroinvertebrate survey would be really excited about it. But I do not think that excitement lasts as you walk away" (3-K12).

Needs That Guide Initial Decision-Making Around Citizen Science

Equipment

82% of participants expressed equipment needs. In general, interviewees wanted vials, dip nets, clipboards, meter sticks, microscopes, thermometers, boots, and waders. Higher education faculty also mentioned ideal equipment like snowshoes or cross-country skis, depending on the terrain. Some K-12 classrooms, and most higher education institutions, said they already had quite a bit of equipment, while others did not. Projects with minimal equipment requirements were appealing, as one interviewee observed,

> "it seems like [this project] does not require a ton of equipment. We have thermometers, but it seems like most of what else you do is observational data collection, and I cannot really think of anything that would improve the students ability to collect that data, as long as they're like wearing boots and winter stuff, which I cannot guarantee that the students will remember to wear boots … they'll still show up in sweatshirts" (6-4yr).

Professional development resources

Educational resources were another need desired by 82% of interviewees. K-12 faculty wanted narrated slide decks or videos on topics like entering, preparing, and using data. Interviewees also expressed interest in resources for specific insect identification and handling–and broader resources that would allow students to look up other specimens that they encountered. Many higher education classrooms had access to resources needed; however, some instructors mentioned that obtaining materials to integrate into the curriculum pertaining to the ecological background of the project would be useful. One instructor reflected on this need.

> "[In] my general ecology textbook … usually there's a little bit on cold adapted organisms but not a lot on insects, I do not think. I like the idea of building up some more video tutorials and things along those lines … using data sets that are out there to … recreate some of the key findings in … papers … or something like that. Or [older research] that's coming out … that'd be cool to get that into some textbooks" (4-4yr).

A desire for laminated cards and handouts with instructions that could be brought out to the field was also mentioned.

Training materials & demonstrations

82% of participants also wanted access to training and demonstrations. Interviewees wanted a clear idea of needs to implement the project, streamlined protocols, and the confidence that the logistics, objectives, and audiences were a match for the teacher. Guidelines and practice "training" sessions with students and peer mentors were also mentioned. According to one interviewee,

> "I like to open it up with what questions the students have and see what they're worried about. And doing our best to answer those, and then taking them out and seeing how it goes. Taking out a small group first does not always work in all situations and settings … but, then adapt and adjust for the larger group. Since we have high school and middle school students, I also lean on peer teaching, so utilizing our older students that have those skills or are trying to build those skills and then have them guide younger students seems to be pretty successful" (5-K12).

One interviewee mentioned that group training and demonstrations could help remove some initial hesitations about new projects, especially if

> "somebody came out and helped us find a stream … and ran through it with us the first time, so I was not a rookie when I did it on my own, that would probably be the biggest barrier removal" (3-K12).

Alignment with class times & schedules

Concerns around time for the field activities and alignment with class schedules were expressed by 55% of participants. Some of the K-12 class periods are very short, which prevents diving deep into a lesson or leaving the classroom. In a 45-minute class period, it can be difficult to get to a natural environment and collect data. Faculty at higher education institutions were also concerned about class schedules, and about matching the semester with the seasonality timing of the project. One teacher suggested,

> "resources that explicitly tie the project to different subjects–including environmental science, physics, chemistry–to increase implementation flexibility" (3-K12).

One interviewee noted that the winter focused projects gave instructors more time for integration during the school year,

> "Field-based in the winter projects are really, really cool. One of the reasons we have not collected data for a lot of other citizen science projects is that they typically are happening when we're not even in session. A [winter-based citizen science project] is a great opportunity" (9-4yr).

Motivations for Participating in Citizen Science Projects

Bring lessons to life & break routine

Opportunities to break routines and get students hands-on experience were motivations expressed by 64% of participants. Faculty consider citizen science projects as opportunities to bring classroom and textbook content to life and increase awareness of local aquatic insects, biodiversity, and different ecosystems in an outdoor, hands-on environment. Teachers imagined their students would be motivated to participate in the project by the opportunity to get outside, leave the classroom, and break routine. Bringing winter science to life was especially of interest, as there are fewer opportunities to make observations in snowy conditions. They wanted students to gain,

> "a greater appreciation for some understudied insects at an understudied time of year" (2-4yr).

Winter ecology was especially compelling, because many educational models ignore winter and the life that invertebrates experience in water near or below freezing temperatures, leaving students to assume that insects typically experience winter like mammals by hibernating. Another interviewee added that they were motivated because,

> "I could tie [the project] into a lot of different things, it is real data collection that kids can do in the off-season … [and can be connected to] climate and climate change, since that is always on kids minds now" (3-K12).

Create enthusiasm for subject

82% of interviewees wanted students to become excited about science and bridge that interest to advanced classes, new career pathways, and research. Interviewees also wanted students to increase their general enthusiasm for environmental topics, issues, and local news. As one interviewee stated,

> "[This project] adds that extra layer onto like, okay, we're not just doing this for the purpose of … checking a box on our learning objectives, but we're actually doing it because we're contributing to … the larger body of science, which is awesome. I mean, that's also what we're here to do is to teach [students] about the process of science and the bigger world" (10-4yr).

Another interviewee added,

> "It's a largely untapped area of science. With climate change, global warming, we're going to see issues with species that can emerge in the wintertime, and that will have cascading implications to other organisms and dynamics. There's so much research left to do in the winter realm" (4-4yr).

Connections

Creating new connections was a motivation expressed by 55% of participants. Teachers were motivated to participate so they could create connections with other teachers, community members, and university staff. Many faculty were especially interested in connections that could lead to professional collaborations and a chance for publication. This was a concern especially for faculty at two-year colleges, where they did not have as much institutional support to conduct formal research.

Connecting their students with the community, science knowledge creation, other classrooms, and the local University was motivating for interviewees, especially faculty from two-year technical colleges.

Teachers and faculty also wanted students to see that they could make a difference through data collection and could show up in their communities as responsible members. As one interviewee said,

> "Even if they're not into science, it's important to learn to volunteer and collect data and be involved in your community. [For my class], I would definitely do a hard sell on the fact that there are members of your community and people at the [University] that are going to use your data to come up with conclusions; you are part of the acquisition of information. That's huge" (1-K12).

For undergraduate students, one interviewee suggested,

> "if there is an opportunity to get together and interact, it would be great for students. They could talk with other citizens or groups that are doing this and see that it is not just an eccentric thing they did as an undergraduate student with [teacher name] but rather it is part of a bigger whole" (2-4yr).

Recognition for students

55% of participants thought that participation in this project would motivate students through opportunities for recognition. One teacher said,

> "I have a wall that says: 'See yourself in science!' It's got pictures of the students doing different things that we've done during the school year. They talk about it all the time, so if I take pictures of them [doing citizen science research] and post it, that will be huge. Students also like whenever everyone else sees them leaving campus for a field trip" (1-K12).

For higher education students, teachers also viewed recognition as an important motivator but in the form of data analysis that students could 'own' and share with others. One interviewee said that a major motivation would be an

> "experience for those that are needing the research piece for graduate school in the future or for getting their first jobs … a big draw is presentation experience, whether that be at our local conference, or even more meaningful, if they can present at a regional or national-level conference or in a publication" (4-4yr).

Life-long learning

64% of interviewees also expressed personal motivations in participating such as ongoing "life-long" learning opportunities, being able to also get family members to participate, and a personal fulfillment in contributing more to the world. As one interviewee stated,

> "I'm really fascinated [by this project], and I think winter is an untapped opportunity, and I've done work on lakes. There is a lot going on, and I think [winter] is really understudied. There are some gaps in our natural history and knowledge of insects in the temperate zone" (2-4yr).

Another interviewee stated,

> "Since there's not a lot known, even seemingly small findings can be publishable too, which is neat" (4-4yr).

Benefits & Experiences Desired

Data-savvy students

Learning how to collect useful data and apply it to a scientific inquiry was one important benefit that 64% of teachers hoped their students would gain from the project. As one teacher said that working with longer term datasets at the K-12 level was valuable and a core skill desired:

> "I'm trying to make sure that kids leave my classes with pretty good spreadsheet and graphing abilities" (3-K12).

Another interviewee added,

> "data analysis research methods and techniques, following a standard operating procedure, and being able to contribute to a larger data set is meaningful" (4-4yr).

Building science knowledge with students & others

90% of participants viewed building scientific knowledge and appreciation through our project and curriculum as a benefit of involvement. Students should understand how their work affects the work of others, and our broader ability to successfully build scientific knowledge. As one interviewee said, citizen science projects can be well

> "suited for students who are doing senior projects, like something, where there's a framework and a connection to the bigger picture. It's not just collecting some data that's gonna get lost in space; it can contribute to something and then students feel a little bit better about it. The nature of [data collection being] geared towards citizen science monitoring makes it conceptually relevant and meaningful" (10-4yr).

Another benefit of participation expressed by most interviewees was that the project could convey key concepts in ecology, such as phenology, adaptation, and interconnection, and could easily be used to train students in the scientific method.

Another expressed benefit of involvement in 73% of participant interviews was the project's relevance to standing curricular topics, broad applications, and general good fit. Many teachers in K-12 settings also expressed that this project could help schools create interesting opportunities for students, leading to more parents buy-in and marketability of the school in terms of providing quality curriculum. Another benefit expressed by many interviewees was the simplicity and ease of the project for students and teachers. One teacher stated,

> "I think one thing is … for teachers … there's so much that they have to do, where … you have to do this worksheet, you have to write this up … and sometimes it's nice to be able to say to [students] all you have to do is collect and submit your data, and that's what your grade for this activity is" (3-K12).

Leadership & communication skills

Development of science communication and leadership skills was expressed as a benefit of our program by 64% of participants. Higher education faculty also saw citizen science projects as an opportunity for students to take the lead on small research projects gaining writing and communication skills. If students brainstormed a research question that could be answered with the data in a team, the project might help them build mentorship, leadership, communication, and collaboration skills, especially if students were able to develop interesting and presentable outcomes. One interviewee shared,

> "it also gives some of those non-tangible experiences, you know, like being a senior undergraduate researcher working you know, sort of being role models" (2-4yr).

Some teachers in K-12 settings were also excited about the opportunity for pairing activities, where older students could take younger students out and complete the activity together. Additionally, many instructors wanted students to come away with communication skills and be able to

> "describe to somebody else what the experiment is, what the value of the experiment is, and why we're conducting the research" (3-K12).

Appreciation for local environment

73% of participants expressed a desire for their students and the larger community to know what's in their backyards. As one interviewee said,

> "Most people that I run into in the parks, it's a new thing and exciting to them and opens their eyes. They know to pay attention when they are walking around or snowshoeing in the state parks or other places in the wintertime" (4-4yr).

Another interviewee added,

> "It is really cool for [students] to see that in an urban environment, you still have these habitats, and our institution is very much about embracing our place in our urban setting … and sometimes that is a little harder with the ecology side of things [compared to the social sciences and humanities]" (9-4yr).

By participating, students would also gain environmental literacy and a sense of responsibility for natural spaces.

Building Ideal Projects

Long-term access & flexibility

When asked to imagine potential ideal projects, 36% of interviewees described projects that would give teachers the ability to return to the same environment, so they could have students study over a longer period and throughout multiple seasons. One example shared by an interviewee is the ability to adopt a section of woods or water near their home school. Other interviewees would like to have the time and resources to explore more seasonal phenology of insect emergence and entire life cycles.

Higher education faculty were interested in semester, yearlong, or even multi-year projects, so students could see change over time. In an ideal world, faculty would have the flexibility to integrate a variety of project based labs and semester-long projects. Some faculty expressed a desire for more time to mentor more undergraduate research experiences that could produce results that were publishable. One faculty participant shared,

> "In an ideal world, I would love to be working on a project with students over time that builds a data set that we can publish, we can refer back to, we can use [and] pull in other students' data so that we have even more to work with. It would be [a] really inquiry-based lab that would take [students] through the scientific process and maybe would take up the whole semester" (9-4yr).

Resource rich

55% of teachers expressed that ideal citizen science projects would be ones that had many resources for classrooms and instructors. For K-12 groups, ideal projects would have budgets for staffing, transportation, and equipment. One interviewee shared that having resources laid out as plainly as possible would help

> "make it [as] easy as possible on staff and administration, to say yes" (5-K12).

Interviewees expressed desire for projects with funding for classrooms to invite experts or the opportunity for university students or faculty to join K-12 classrooms or accompany groups on field trips to assist with data gathering. One teacher referenced a project as an example,

> "At [university name], they would send some students in master's program to come do simple labs with my students–and there were lots of women and people of color–and it was an amazing experience for my students to see scientists who were not old like me or all men and not all white" (1-K12).

Another interviewee said,

> "I think what would really motivate more people to participate, or myself to participate, is if you had people that were really compelling and brought insects that you could schedule to come into the school" (3-K12).

Opportunity for science communication

45% of participants also expressed that ideal projects would provide students with opportunities for learning about and practicing science communication and teaching. Higher education faculty expressed an interest in incorporating science communication opportunities for undergraduate students into their ideal projects. As one interviewee said they'd like

> "a part of [the project] that was about science communication for the students, if there was some piece that was not just reporting the results that could give them experience explaining topics to public audiences and more awareness of science communication career paths" (9-yr).

Communities of practice

73% of interviewees shared that they would like a project that provided a community of practice or working groups of other teachers or faculty outside their current institutions but involved in the same project to help troubleshoot. One faculty member shared that this was especially attractive to primarily undergraduate institutions with limited collaborative opportunities,

> "so having a network of collaborators is kind of nice [to] bounce ideas off [of]" (2-4yr).

DISCUSSION

Recent research on citizen science engagement has focused on investigating intrinsic motivations of participants and affective, behavioral, and cognitive engagement, in contrast to previous studies, which focused on quantifiable measurements of engagement related to data acquisition (Phillips et al., 2019). Our paper contributes to the literature on qualitative, in-depth description of motivations and engagement with citizen science projects by involving an analysis of the stakeholders in varied education settings. Additionally, we present features that make citizen science programs initially attractive to both primary and post-secondary teaching institutions.

Most citizen science programs focus on ecological and environmental programs typically conducted over the summertime or during the growing season (Gal, 2019; He & Wiggins, 2017; Paige et al., 2012; Tyson, 2019), and many studies on citizen science engagement do not mention specifics about the programs other than their broad characterization within the fields of natural or physical sciences (Phillips et al., 2019; Vance-Chalcraft et al., 2022). Thus, there is little evidence to indicate the commonality of programs involving a winter focus and the opportunities and barriers that these types of programs may impose or provide. There are a growing number of programs within the field of freshwater ecology with classrooms (typically K-12) being involved in water quality monitoring and watershed management (França et al., 2019; Rosen et al., 2016). However, these programs typically are conducted over the warm months of the year.

Our study focuses particularly on a citizen science program involving winter research in the field of freshwater ecology. Although winter has a long history of study in many different fields (Lee & Denlinger, 1991; Smedley & Wickman, 2017), freshwater ecological research over winter is still a relatively new area of study with new discoveries being made (Anderson et al., 2022; Bodmer et al., 2023; Bodmer & Nyquist, 2022). A winter field experience may offer students a hands-on learning opportunity during a time when many might not venture outside. This study offers insight into barriers and opportunities for involving the public in this new and growing scientific area of inquiry.

Motivations & Benefits

In our study, we identified certain motivations and benefits that were shared among faculty and teachers, which we believe are underrepresented in the literature. The first of these is a personal motivation for life-long learning and the opportunity for faculty instructors to stay connected with their identity as scientists. This was especially important for faculty from 2-year and teaching-heavy institutions, which did not have as many opportunities for research. There is indication that citizen science programs help contribute to scientific identity and community for both adults and youth (Ballard et al., 2017, 2018; Paige et al., 2015). Future research should continue to explore initial and long-term needs, motivations, barriers, perceptions of identity, and opportunities for citizen science with two-year and technical college faculty. Instructors in our study expressed that participating in a citizen science community of practice would aid them to become better equipped and more engaged participants. This insight lends utility to building communities of practice in citizen science programs, not only for the benefit of students as presented by Koomen et al. (2018), but for teachers at higher education institutions as well.

Many K-12 teachers and higher education faculty in our study were intrigued by the ability of our citizen science project to enhance curricula and recognition. Although most studies investigating citizen science participation in schools have found benefits to students in regard to particular learning outcomes [e.g., formulating hypotheses and analyzing data (Chen & Cowie, 2013; Gal, 2019; Koomen et al., 2018; Vance-Chalcraft et al., 2022)], there has been little focus on benefits to curricula and recognition. Paige et al. (2015) describe teacher participation in professional learning centered around citizen science as a way to enhance pedagogy and school-based curriculum. Our study builds on this by also showing that instructors appreciate citizen science programs that highlight high-quality classroom engagement to parents, school administrators, and the community.

Hesitations & Needs

In regard to hesitations, needs, and challenges, much discussion around data issues within citizen science programs focus on data accuracy (Dickinson et al., 2010), reproducibility and detection probability (Cooper et al., 2012), which are legitimate concerns for producing reliable data for scientists. Another challenge faced by scientists with citizen science data is incentivizing participants to follow through with submitting data to databases (He & Wiggins, 2017). A lack of incentive for submitting data may arise from "zero data" or "zero count" data, which are observations of absences when no species are encountered and may be deemed as uninteresting by volunteers (Cooper et al., 2012). This is a challenge associated with ecological science when animal observations are part of the data collection and one that affects participant engagement and motivation.

In our study, we encountered trepidation around "zero count" data by some of our interviewees, especially as it related to maintaining continued motivation in students. Some ways to overcome this challenge have been put forth, including creating space for observers to add any other observations and to formulate questions that can always have a yes answer rather than yes/no answers (Cooper et al., 2012). Many of our interviewees expressed that open access data with lesson plans to go along with data analysis would be an added attraction and help provide work for students if they were not able to collect their own data. Therefore, providing open access data opportunities and directions for data analysis in the classroom, and creating questions with value around zero data may help other projects increase volunteer engagement with data and incentivize data submission.

Within investigations of classroom involvement in citizen science programs, there is some discussion around field safety (He & Wiggins, 2017). He and Wiggins (2017) mainly discuss concerns around students' sense of safety given backgrounds from urban areas with gun violence. Our study found concerns around field safety that are likely unique to this study given its winter and aquatic nature. Another concern brought up by our interviewees was surrounding equity and field access. There is a growing awareness and concern in the field of ecology over equity and accessibility in labs and field work (Burgstahler, 2012; Ramírez-Castañeda et al., 2022). There has been an increase in attention to diversity, equity, and access within citizen science programs as well (Paleco et al., 2021). Our study indicates a concern over diversity and access for field-based research projects.

CONCLUSIONS & IMPLICATIONS

Ideal Characteristics of Citizen Science Projects

Through our project, which focused on in-depth interviews with teachers and faculty, we are able to provide more detailed characteristics of ideal citizen science projects, so activity participation is more intensive and learner-centered. Our findings indicate that many barriers such as transportation, time availability, and safety are shared among K-12 instructors and higher education faculty. Many of these concerns are especially poignant for K-12 schools since they may not have as much access to resources as higher education institutions and some of these barriers have been discussed with field trips in general (Behrendt & Franklin, 2014). Our recommendations include working closely with teachers and administrators to overcome these barriers, providing extra funding for busing, and creating additional ways for volunteers to contribute to the project beyond data collection, such as data analysis utilizing open access databases.

The interest among interviewees indicates that there is an opportunity for more winter-focused citizen science research, which remains an untapped area of both scientific research and citizen science involvement. Many of our participants indicated an interest in local or regional projects that could even be conducted close to homes or schools, indicating an interest in learning more about local environments. Future projects should tap into this interest by offering local programs with rich educational materials. We also recommend programs focus on building opportunities for collaboration, support groups, peer mentoring, and science communication.

Based on our interviews, we also suggest providing in-person or digital training events even for higher education faculty, which may help teachers and faculty feel more confident in bringing students out into the field and help build a sense of community. This opportunity may help maintain scientific identity for faculty at teaching colleges. Therefore, we recommend that programs put effort into training resources and in-person visits and events to support volunteers. Training events with graduate students or citizen science staff may also help students see increased representation within STEM fields and learn about higher education opportunities. Many teachers in our study indicated how university visits to their classrooms were very motivational for their students and helped students see more BIPOC (Black and Indigenous People of Color) and gender minorities in STEM.

Our study focused on in-depth, qualitative data, and thus, we recognize limitations in the reproducibility and generalization of our findings. This is a limitation simultaneously recognized in science education research but also utilized for its effectiveness in raising issues for further discussion and future study (Koomen et al., 2018). Implementing insights and continuing research to improve citizen science projects for all types of classrooms and learners is important for increasing public interest, engagement, and trust in science.

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