CITIZEN SCIENCE:
THEORY AND PRACTICE

Accessibility of Participation in a Pollinator-Focused Community Science Project

CASE STUDIES

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ABSTRACT

Ecological research, education, and community engagement were interrupted globally in the spring and summer of 2020 because of the COVID-19 pandemic. To allow for continued data collection and to provide opportunities for people to interact with nature, we developed a community science project focusing on pollinator visitation to gardens and lawns. To evaluate the accessibility of this project to volunteers, we conducted 28 semi-structured interviews with people who participated in the project training. Interviewees experienced a number of barriers to participation, the most common of which were difficulty with the data collection procedure (n = 22), challenges using technology (n = 11), and lack of access to technology (n = 9). However, components of the online training and data collection procedure helped overcome some of these barriers. Strategies such as using a hybrid training format, simplifying the use of technology during training, and incorporating active learning into online workshops could increase participation in community science projects, both in the context of the pandemic and moving forward.

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INTRODUCTION

Ecological research, education, and community engagement were interrupted globally in the spring and summer of 2020 because of the COVID-19 pandemic (Marinono, Land, and Jensen 2020; Osafo 2020; Radecki and Schonfeld 2020). Research during this time was limited to "essential" activities, and many ecologists canceled their field seasons (Radecki and Schonfeld 2020). Additionally, both formal and informal in-person education was stalled for K–12 and university students as well as for adults (Marinono, Land, and Jensen 2020; Osafo 2020). Outreach programs paused many activities and moved others online (Main, Ober, and Johnson 2020; Osafo 2020). The resulting lack of ecological research and education may be remedied in part through the use of community science.

Community science refers to participation in research by people who are not professional scientists and is also frequently referred to as "citizen science" (Kovaka 2021; Tulloch et al. 2013). In recent years, many organizations promoting public participation in scientific research have transitioned to the term "community science" to recognize that participants come from diverse backgrounds and are not necessarily citizens of any particular country (Fuller 2020; National Audubon Society 2022). We use the term "academic scientists" to refer to researchers who are formally affiliated with a university (Eitzel et al. 2017).

Ecologists often use community science to increase the size of their datasets through crowdsourcing and to provide opportunities for public engagement and science education (Bonney et al. 2016). While the need for social distancing during the pandemic caused some community science projects to pause activities (Escoto-Murillo and Alfaro 2021; Lepenies and Zakari 2021), others have been conducted fully online and have seen steady or increased participation (Basile et al. 2021; Crimmins et al. 2021). Some projects that previously included in-person training moved online to allow their continuation (Dwivedi 2020; Smith and Hamed 2020). Additionally, new projects have been developed to provide a source of data during lockdowns and to create opportunities for students to engage in the scientific process remotely (Arbeláez-Cortés et al. 2021; Oberbauer et al. 2021). Outdoor projects that can be conducted at home were particularly popular during the early months of the pandemic (Drill et al. 2022).

Implementation of community science during the pandemic was impacted by the ability of individual volunteers to participate. Inequities in the accessibility of community science existed before the pandemic, particularly for groups historically underrepresented in science and those with lower incomes (Hobbs and White 2012; Pandya 2012). These inequities were exacerbated by the pandemic. For example, people who do not have internet access and children who do not have a parent available at home to help them are often unable to participate in online community science projects (Smith and Hamed 2020; Van Haeften et al. 2020).

Prior to the pandemic, we had been planning a field season in Chicago, IL USA, focusing on the visitation of pollinators to different types of green spaces along an urban-rural gradient. However, because of our inability to conduct socially distanced fieldwork in an urban setting, our field season was canceled. Simultaneously, educational and volunteer opportunities offered by Illinois environmental organizations such as the Master Gardener and Master Naturalist programs (IE 2022a,b), neighborhood gardening groups, and school environmental clubs were reduced or canceled entirely. So, we instead developed a community science project that would allow data collection during the 2020 field season and provide opportunities for the public to participate in a meaningful outdoor activity during the lockdown period. Our research interests were particularly well-suited to community science during the pandemic because volunteers could remain close to home while collecting data from their yards or neighborhood green spaces. Additionally, our research focused on insect pollinators, a charismatic functional group that is easily observable in urban and suburban settings. Here, we describe our project, evaluate its accessibility, and consider factors that impact participation in community science during the COVID-19 pandemic and in a world after pandemic restrictions have been lifted.

METHODS

Our project engaged community scientists in monitoring pollinator visitation to gardens and lawns in their neighborhoods. Training and data collection began in June 2020 and concluded in November 2020. Data collection was followed by an evaluation of the accessibility of the project to participants; the evaluation was conducted between September 2021 and January 2022.

COMMUNITY SCIENCE PROJECT DESIGN AND IMPLEMENTATION

Project goals

We had two overarching goals. First, we wanted to maintain data collection during the lockdown period that occurred in 2020. Our research interests were focused on understanding the impacts of urbanization as well as social variables such as race and income on pollinator abundance. Second, we wanted to provide opportunities

for people to connect with nature and to engage with the scientific process during the lockdown period. In this paper, we focus on understanding the extent to which the project was able to create opportunities for nature engagement by evaluating the accessibility of participation in the project. Ecological results describing patterns of pollinator abundance will be presented elsewhere.

Recruitment

Volunteers were recruited by contacting environmental and gardening organizations located in Illinois, USA. We contacted all Illinois Master Gardener and Master Naturalist groups in the state (IE 2022a,b) as well as all gardening organizations in the greater Chicago area for which we could find publicly available contact information. Additionally, we contacted individuals, schools, and organizations with whom we had previously collaborated.

Training

All community scientists participated in a two-hour (Zoom Video Communications 2022) training session delivered by Zoom before beginning data collection. We began the training with a short lecture reviewing the topic of global pollinator declines, proposing the idea that urban areas may play an important role in pollinator conservation, and sharing the results of our previous research focusing on urban pollinators. Next, we reviewed the identifying characteristics of thirteen broad groups of pollinators, using Zoom polls (Zoom Video Communications 2022) to provide participants with opportunities to practice identification. Participants then worked in small groups in Zoom breakout rooms (Zoom Video Communications 2022) to identify a series of specimen photos. We put these photos into a Google Doc (Google 2022) and shared the link with participants. Participants were asked to open the link, review the photos, and write what they thought was the correct pollinator group for each photo. After coming back together to review the correct answers in a large group and address points of confusion, participants were asked to go outside and complete a practice survey. Finally, they returned to the Zoom room (Zoom Video Communications 2022) to share their experiences observing pollinators and ask questions that occurred to them during their practice survey.

We held 12 training sessions attended by a total of 161 participants. Training sessions were conducted in May and June of 2020 during daylight hours to allow for outdoor practice. After each training session, attendees were emailed a copy of the presentation and the data collection sheet as well as a PDF of the "Upper Midwest Citizen Science Monitoring Guide for Native Bees" (Jordan, Lee-Mäder, and Vaughan 2016).

Data collection

Community scientists were instructed to select one or more study sites to monitor throughout the summer and fall. They could select an ornamental garden, a vegetable garden, a registered pollinator garden, or a lawn. If their selected garden or lawn was very large, they were asked to select 152.4 m^2 (500 ft^2) within it to monitor. There was no minimum site area required for participation. Some participants opted to monitor two sites.

Community scientists were asked to conduct pollinator surveys at their selected site(s) at two-week intervals between June and November. During each survey, they spent 30 minutes walking slowly through their garden and recording all arthropods or birds that they observed landing on the reproductive parts of a flower. They were instructed to time themselves in a way that would allow them to observe the full site, and to spend the most time observing the most active flowers (methods modified from Hülsmann et al. 2015; Jordan, Lee-Mäder, and Vaughan 2016). Pollinators were identified to the same 13 groups presented during training.

Participants also recorded the site type, plot size, and environmental data including temperature, wind speed, and cloud cover on each visit. We recommended participants use either an app or a thermometer to collect temperature data and instructed them to categorize wind speed based on the Beaufort scale (Jordan, Lee-Mäder, and Vaughan 2016). We asked them to collect data between 0900 and 1700 on sunny days when the wind speed was below 16.1 km/hour (10 mph) because pollinators tend to be most active under these conditions. Finally, community scientists could submit their observations through an online Qualtrics survey (Qualtrics 2020), by email, or by mailing a hard copy of their data collection sheet.

EVALUATION OF PROJECT ACCESSIBILITY

To evaluate the accessibility of this project, we conducted 28 semi-structured interviews with 29 people who attended project training sessions. One couple who participated in the project together requested to be interviewed together. Our goal was to obtain a sample size that would allow us to reach "saturation," or a point at which conducting additional interviews does not produce new information (Guest, Bunce, and Johnson 2006). Saturation is generally reached within 20 interviews in qualitative studies using semi-structured interviews and with a relatively homogenous population (Guest, Bunce, and Johnson 2006; Morgan et al. 2002; Namey et al. 2016).

To recruit interviewees, we emailed an invitation to all people who attended a project training session. Two months after the invitation was sent, we began to send follow-up emails to randomly selected groups of 20

training attendees. We sent follow-up emails to one group of attendees every other week until we had scheduled 25 interviews. Because we conducted interviews with all attendees who responded to the follow-up email, and we received more responses than we needed, this resulted in a total of 28 interviews.

Interview questions focused on engagement in community science during the pandemic, barriers to participation in our project, access to and use of required technology, and recommendations for improving project accessibility (Supplemental file 1: Appendix 1). We were interested in understanding barriers resulting from the pandemic as well as barriers that are likely to continue to impact participants now that pandemic restrictions have been lifted. Interviews were conducted by Zoom or by phone between 24 September 2021 and 17 January 2022. All interviews were recorded and transcribed (Supplemental File 1: Appendix 1).

Data analysis comprised several rounds of qualitative coding (Saldaña 2021). In our first two rounds, we divided the information from the interviews into categories based on the topic being discussed (e.g., technology use, access to green space, data collection). The third round involved the use of in-vivo and process coding to explore the content of the interviews more deeply. In-vivo codes are words or short phrases used by the interviewees, whereas process codes are gerund verbs describing the activity of interviewees. In-vivo and process codes were developed a posteriori based on the content present in the interview data (Saldaña 2021). Finally, in our fourth round, we consolidated the codes from round three to identify a list of all barriers to participation and factors that facilitated participation identified by interviewees (Supplemental File 2: Appendix 2).

RESULTS

Community scientists submitted a total of 390 pollinator surveys conducted at 81 study sites. Three hundred forty-seven surveys were submitted via the online submission form, whereas 30 were submitted by email, and 13 were submitted by postal mail. Owing to privacy concerns, we did not ask community scientists to record their names on their data submission forms. However, we can estimate that the total number of people who collected data was slightly less than 81 of the original 161 workshop participants, given that a few people indicated they were planning to collect data at multiple study sites. Interviewees had a much higher rate of participation in data collection, with 26 of 28 having submitted at least one pollinator survey during the study period.

BARRIERS TO PARTICIPATION

The most frequently reported challenge, noted by 22 participants (79%), was difficulty identifying pollinators in the field (Table 1). Interviewees explained that many pollinators are quite small and move quickly. Some also found that pollinators from the different groups could sometimes look similar and that their lack of experience with insect identification may have contributed to their difficulty. In addition to problems with identification, several interviewees noted that it could be challenging to get an accurate count of pollinators present at their study sites. They explained that it was sometimes difficult to count pollinators when they were particularly abundant, and that at times it was hard to know whether a pollinator that they observed had newly arrived or had already been recorded at a different flower.

Many community scientists overcame difficulties with data collection by referring to training materials, insect identification books, or information available online. One common strategy was to take photos of unknown pollinators during data collection and confirm the identification afterwards. Participants often reported talking to each other or emailing an academic scientist involved in the project for clarification. Despite the use of these tools, problems with insect identification appeared to present a real barrier to participation in the project. One interviewee explained that she almost decided not to submit her data due to concerns about accuracy. She said, "Because I wasn't exactly sure what I was seeing, I did not want to send in my paperwork... It just kind of stopped my participation."

Difficulty using technology and a lack of access to technology were the second and third most common factors identified as barriers to participation in the project, reported by 11 (39%) and nine (32%) participants, respectively. The most frequently reported access issue was problems with internet connectivity. Regarding technology use, some participants did not know how to use Zoom or Google Docs (Google 2022; Zoom Video Communications 2022), experienced technological malfunctions during the training, or simply did not enjoy the time spent at the computer. Additionally, several had trouble with the online data submission portal or had difficulty taking clear photos for insect identification. While no interviewees reported that a lack of access to technology or technological difficulties prevented them from participating, it was clear that issues related to technology did impact the quality of the experience for some. For example, a long lag time resulting from a poor internet connection made it difficult for one interviewee to participate in small group discussions, while another was unable to ask questions because she did not know how to

BARRIER	NUMBER OF PARTICIPANTS	EXPLANATION
Difficulty with data collection procedure	**22**	
Pollinator identification	21	Difficulty identifying pollinators during data collection. Participants noted a number of factors that made identification difficult, including difficulty seeing insects that were small and/or moving quickly, difficulty remembering the identification groups, a lack of prior knowledge or experience, and the fact that sometimes two different species can look very similar.
Pollinator counts	5	Difficulty getting an accurate count of pollinators when they were particularly abundant, or not knowing whether an individual pollinator had already been counted.
Site selection	1	Difficulty measuring a potential study site and deciding which flower patches within a garden to include.
Understanding instructions	1	Confusion about the level of detail needed in pollinator identification.
Use of technology	**11**	
Data submission	6	Finding data submission to be difficult due to technological problems or not knowing how to use the online form or finding data submission to be time consuming.
Participation in training	6	Finding participation in the online training difficult owing to problems using Zoom or Google Docs, a lack of confidence using technology, or not enjoying training conducted in an online format.
Difficulty using camera	3	Difficulty getting photos of pollinators that are clear enough to be usable for identification purposes.
Access to technology	**9**	
Access to internet or computer	8	Not having Wi-Fi at home, having problems with internet connectivity that interfered with participation in the training, or having an older device that made participation more difficult.
Access to printer	1	Not having access to a color printer that could be used to print the insect identification materials that were provided electronically.
Access to camera	1	Not having access to a camera that can take high-quality photos.
Time to participate	**5**	Not having time to participate in the project for reasons that included working or taking on extra responsibilities because of the COVID pandemic (e.g., childcare).
Health and physical disability	**5**	
Physical health	3	An injury or illness that prevented participation in the project. No participants said that getting COVID themselves prevented them from participating.
Mental health	2	Difficulty participating due to emotional strain caused by the COVID pandemic.
Mobility	1	Difficulty accessing study sites due to a physical disability.
Vision	1	Difficulty seeing pollinators due to vision loss.
Access to pollinators	**4**	Having limited access to high-quality garden areas in which to monitor pollinators, or low pollinator activity in nearby green space leading to boredom during data collection.
Weather	**2**	Weather conditions that either made it unpleasant to be outside (e.g., heat) or that were outside of the conditions required for data collection (e.g., rain, full cloud cover).
Not kid-friendly	**1**	Children not wanting or being able to participate, and parents having difficulty participating because their children do not want to participate with them.
Pet interference	**1**	Difficulty with data collection due to a dog chasing pollinators away from the plants.
Public spaces crowded	**1**	Not wanting to collect data in crowded public spaces, in particular after the first few months of social distancing when people resumed spending more time outside of their homes.

Table 1 Barriers to participation in a pollinator-focused community science project occurring during the COVID-19 pandemic. Barriers were identified based on interviews with people who attended a community science training in the Spring of 2020. Interviews were conducted by Zoom between September 2021 and January 2022.

use the Zoom chat feature (Zoom Video Communications 2022).

For five participants (18%), issues related to health and physical disabilities presented an additional barrier. While no interviewees reported that contracting COVID impacted their participation, one community scientist said that a family member died of COVID during the project period and that as a result, she took on additional family responsibilities that limited her ability to participate. Mental health concerns were also cited as a barrier. For example, one interviewee noted that stress caused by living through the pandemic impacted her participation in the project. They explained, "the pandemic was such a weird time and I think we all felt so shut down and dysfunctional that the thought of doing anything just seemed like a lot of work."

Limited access to high quality pollinator habitat and low levels of pollinator activity were identified as barriers by four participants (14%). While all interviewees reported having access to either a garden or a lawn in which to collect data, several noted that data collection was less fun at sites with lower levels of pollinator activity. While they were aware that the data they collected were still valuable despite the low pollinator abundance, some people felt that the quality of their experience was reduced.

Finally, five interviewees (18%) reported that it was difficult to find the time to participate in this project owing to responsibilities that included work and childcare.

The two interviewees who did not collect data identified their main barriers to participation as serious health problems and busyness resulting from work and parenting. Additionally, they noted a lack of pollinators at the study sites they were planning to use and a difficulty with pollinator identification.

FACTORS FACILITATING PARTICIPATION

The most frequently mentioned factor facilitating participation, noted by 20 interviewees (71%), was the project training (Table 2). Several confirmed that the

FACILITATING FACTOR	NUMBER OF PARTICIPANTS	EXPLANATION
Training aspects	**20**	
Reference materials	11	Participants were sent PowerPoint slides from the training, including information about pollinator identification.
Group work in breakout rooms	8	Participants practiced identifying photos of pollinators in small groups in Zoom breakout rooms.
Content covered	5	Some participants noted that the information covered during the training was helpful for them during data collection. In particular, some people appreciated the information about pollinator identification.
Zoom polls	3	During the overview of key characteristics to be used for pollinator identification, periodic Zoom polls were used to check understanding and provide an opportunity for practice.
Time for questions	2	Time was set aside for question-and-answer periods at several points during the training.
Hands-on practice	1	Participants were given time during the training to go outside and practice the data collection procedure in their yards.
Clarity of instruction	1	One participant noted that the instructions for the data collection procedure were clear and easy to follow.
Data collection procedure	**17**	
No travel required	12	Participants saved time and avoided unpleasant weather or road conditions by being able to participate in the training from home.
Data collection easy	5	The data collection procedure is easy to learn and does not require prior expertise.
Time commitment small	4	Participants were asked to collect data once every two weeks over the course of the summer and fall.
Timing flexible	3	There was not a set day and time at which data must be collected. Participants could choose the day and time that works best for them.
Study site flexible	1	The study site could be any garden or lawn and there was no minimum study site size. Participants were able to collect data from their own yards.

(Contd.)

FACILITATING FACTOR	NUMBER OF PARTICIPANTS	EXPLANATION
Data submission procedure	**10**	Some participants noted that they found the data submission procedure to be simple and straightforward. There is also flexibility in that participants can either submit their data through an online portal or send it by mail.
Data collection support	**8**	
Collaboration between community scientists	4	Community scientists helped each other identify specimens by sharing photos in a group chat that they created. Some participants signed up for the project with a spouse or friend and helped each other throughout the project.
Collaboration with academic scientists	6	Academic scientists were available to answer questions by email. Additionally, an optional question and answer session was held mid-summer.
Technology use	**8**	
Experience using technology	7	Some community scientists noted that their prior experience using computers and the internet as well as specific programs such as Zoom and Google Docs made it easy for them to participate in this project. Several community scientists noted that as a result of the pandemic, they had already learned how to use Zoom before they participated in my project.
Enjoy using technology	1	One community scientist noted that her enjoyment of technology has made it easy for her to keep up with new developments and programs, which helped her during this training.
Technology easy to use	1	One community scientist thought that Zoom is a relatively easy program to learn.
Access to technology	**4**	
Access to camera	2	Some community scientists said that having access to a nice camera that allowed them to take pictures of pollinators to help with identification was helpful.
Access to computer or internet	2	Some community scientists said they were aware that their access to the computer and the internet made it easy for them to participate in this project.
Access to green space	**3**	Community scientists noted that having access to green space allowed them to easily participate in this project. Some noted their access to native plants and high-quality pollinator habitat.
Ecological factors	**3**	
Pollinator abundance/ diversity low	3	A few community scientists said that they tended to see a few common species at their study sites, which made identification easier.
Slow pollinators	1	One community scientist said that the pollinators didn't move as fast as some other insects, which made it easier to get a look at them.
Experience with ecology	**2**	Community scientists noted that their prior experience with pollinators or with other ecological projects helped prepare them to participate in this project.
Appreciation for the outdoors	**1**	One community scientist said that her enjoyment of time spent in nature provided motivation to participate in the project.
Retirement	**1**	One community scientist recognized that being retired allowed her to be available at the times of day that pollinators tend to be most active.

Table 2 Factors facilitating participation in a pollinator-focused community science project occurring during the COVID-19 pandemic. Facilitating factors were identified based on interviews with people who attended a community science training in the Spring of 2020. Interviews were conducted by Zoom between September 2021 and January 2022.

content provided them with the knowledge and skills that they needed to participate in the project, and said that the materials provided were useful references during data collection. Additionally, participants noted that training components, including question-and-answer periods, practice in small groups, and the use of Zoom polls (Zoom Video Communications 2022) to check understanding, increased their confidence with pollinator identification.

The structure of the data collection and submission procedures were also identified as factors that made it easier to participate in the project by 17 (61%) and ten (36%) participants, respectively. Interviewees noted that the data submission procedure was straightforward and flexible, and they appreciated that they had the option to either submit the data online or send it by mail. Participants noted that the data collection procedure was

straightforward, easy to learn, and did not require prior expertise. Some found that the time commitment was reasonable and appreciated the flexibility of being able to collect data any time between 900 and 1700 h on any day with the appropriate weather conditions.

Eight participants (29%) noted that collaborating with each other and with academic scientists helped them overcome barriers related to pollinator identification. Community scientists involved in the project created a Facebook group that they used to share photos and ask questions. Some participated in the project with a friend and helped each other via phone or email. Additionally, community scientists could email academic scientists to ask questions or confirm identifications, and several optional mid-summer question-and-answer periods provided opportunities for participants to clarify points of confusion.

Participants noted that in some ways, the online format of the training made it even easier for them to be involved in the project than it would have been under normal circumstances. Twelve interviewees (43%) explained that it was convenient not to have to drive to the training. They saved time and avoided unsafe road conditions. For some, not needing to drive also improved the quality of the experience. For example, one person noted that "the nice thing about the online training is being able to connect with people from across the state, not just my local group."

Participants were also aware that personal circumstances made it easier for them to be involved in the project. Four and three interviewees (14% and 11%), respectively, noted that access to technology and pollinator habitat facilitated their participation. Additionally, seven (25%) said that prior experience with technology was helpful. The shared experience of the pandemic contributed to many participants' familiarity with technology. Many interviewees were already accustomed to using Zoom (Zoom Video Communications 2022). One explained, "That's COVID bread. Everything I've been doing has been by Zoom."

DISCUSSION

Many of the barriers encountered by community scientists participating in our project were caused or exacerbated by COVID-19, whereas others were present before 2020 and will likely continue to impact engagement regardless of the pandemic's progression. For example, some technological barriers were the result of the online training. This includes issues with internet connectivity or computer access experienced by eight participants, and difficulties using technology during the training experienced by six participants. Additionally, interviews suggest that difficulties with the data collection procedure may have been exacerbated by the need for social distancing. Three interviewees noted that they would have felt more comfortable with pollinator identification if they had been able to observe physical specimens during the training. Similarly, the pandemic reduced the free time that people had to participate in the project by creating additional caretaking responsibilities for some, and led to a lack of access to pollinator habitat by preventing travel for data collection. Stress caused by COVID-19 also created or exacerbated mental health challenges that impacted participation for two interviewees.

Most barriers that impacted participants in our project would have been present to some extent even if the COVID-19 pandemic had not occurred. Difficulties with the data submission portal would have been present regardless, and participants likely would have found it difficult to identify pollinators in the field under any circumstances. Busyness, lack of access to green space, and health problems are barriers that existed prior to the pandemic and are likely to continue to impact many people even as pandemic-related interruptions fade.

Our study may provide incomplete information about barriers that fully prevented participation in our project. Because most people who provided interviews also collected data, we have limited information about barriers experienced by people who attended our training but did not collect data. It is possible that these people experienced barriers differently. On the basis of the information provided by the two interviewees who did not collect data, it appears that some people were unable to participate because they experienced emergencies in their personal lives or because they were busy with responsibilities such as working and raising a family.

Inequities in the types and magnitudes of barriers experienced by different groups of people likely contributed to our relatively homogenous group of community scientists. Although we did not collect demographic information, we did observe that, on average, data were collected from wealthier and whiter neighborhoods than the state average (USCB 2019). It may be that people belonging to certain groups experienced more barriers that tend to completely prevent participation. For example, people belonging to marginalized groups often live farther away from green space (Saporito and Casey 2015; Schell et al. 2020); are required to work unpredictable hours, including mandatory overtime (Danziger and Boots 2008); and experience reduced access to health care (Orentlicher 2018). New challenges brought about by the pandemic also disproportionately impact marginalized groups. For example, people of color and people from lower-income households were nearly twice as likely to experience

internet connectivity issues when attempting to access educational material during the pandemic (Means et al. 2021).

Although COVID-19 exacerbated many barriers to involvement in our project, it also increased accessibility for twelve interviewees by allowing them to participate from home. This demonstrates a tradeoff in which some community scientists are negatively impacted by the transition to online training while others are positively impacted.

As two interviewees noted, one way to maximize the accessibility of participation in community science projects could be the use of a hybrid training format. The training could be organized in a way that allows participants to attend either in person or via Zoom (Zoom Video Communications 2022), depending on their preference. Hybrid learning has become more common as the development of vaccines and treatments for COVID-19 have reduced the severity of health risks associated with in-person events. Research suggests that learners in hybrid settings build social relationships with teachers and classmates, feel they have more control over their learning, and achieve similar test scores as learners in fully in-person settings (Raes et al. 2019). A hybrid format would allow people who face technological barriers to participate in person while allowing those who face transportation and other barriers to participate online.

In cases in which a fully online format is preferred, technological barriers may be reduced by simplifying technology use during the training. For example, activities using breakout rooms could be replaced with activities that can be conducted with the full group. The downside to this is that it would likely lead to less use of active learning. Because active learning improves student performance and disproportionately benefits learners belonging to marginalized groups, this change could lead to community scientists feeling less prepared to collect data after completing the training (Haak et al. 2011; Freeman et al. 2014). Another option would be to use an asynchronous format for the training since this is often more accessible to learners with limited internet connectivity (Means et al. 2021). The University of Illinois' I-Pollinate and the University of North Carolina's Caterpillars Count are examples of asynchronous projects. However, asynchronous learning interferes with cooperation and can negatively impact cognitive processes and learning outcomes (Guo 2020; Peterson, Beymer, and Putnam 2018).

Incorporating active learning into online training may help prevent difficulties with the data collection procedure. Although it can be more challenging to incorporate active learning online, doing so may improve understanding of content, critical thinking skills, motivation, and enjoyment (Means et al. 2021; Nguyen et al. 2021; Rossi et al. 2021). In this project, we used Zoom polls, breakout rooms, and outdoor practice to incorporate active learning.

Simplifying the pollinator identification categories used by community scientists is another strategy that may improve the accessibility of data collection. While there is evidence that community scientists can detect trends in pollinator abundance and accurately identify pollinators to broad taxonomic groups, it is common for them to struggle when they are asked to identify pollinators to taxonomic levels narrower than order (Kremen, Ullman, and Thorp 2011; Roy et al. 2016). This suggests that participants' concerns about pollinator identification were likely associated with actual errors in pollinator identification. To address this in our ecological study, we consolidated the 13 pollinator groups identified by community scientists into nine broader groups that were used for data analysis. Using this smaller set of pollinator groups at the data collection phase would likely increase community scientists' success in accurately identifying pollinators, which could, in turn, improve self-efficacy, enhance science identity, and increase participants' confidence in their ability to contribute meaningfully to the projects' goals (Chemers et al. 2011; Hiller and Kitsantas 2014).

It may be possible to improve the equity of access to community science projects by targeting barriers that were experienced by people who were unable to participate and that are known to disproportionately impact marginalized communities. For example, time barriers were experienced by interviewees who did not collect data, and members of marginalized groups are more likely to experience scheduling issues due to unpredictable work hours (Danziger and Boots 2008). This barrier could be addressed by breaking trainings into modules that can be completed in short segments, reducing the frequency or length of surveys, or providing compensation to participants (Pateman et al. 2021).

CONCLUSION

Barriers to participation in community science that we have identified through this study occurred in the context of the COVID-19 pandemic but are likely to be relevant in a post-pandemic world as well. While technology use was particularly essential during the pandemic because of the need for social distancing, online training and data submission were frequently components of community science projects prior to the pandemic and will continue to be used in years to come. Participation in community science has been shown to provide a number of benefits, including opportunities for learning about ecological topics,

the development of a stronger sense of place, and an increased interest in and identification with topics related to science and conservation (Bonney et al. 2009; Hiller and Kitsantas 2014). Implementing changes to address barriers to participation will provide opportunities for more people to engage in these valuable experiences.

DATA ACCESSIBILITY STATEMENT

Transcriptions of interviews and examples of coding are available in the Appendices.

SUPPLEMENTARY FILES

The supplementary files for this article can be found as follows:

- **Supplemental File 1: Appendix 1.** Interview transcriptions. DOI: https://doi.org/10.5334/cstp.557.s1
- **Supplemental File 2: Appendix 2.** Codebook. DOI: https://doi.org/10.5334/cstp.557.s2

ETHICS AND CONSENT

This study gained approval from the University of Illinois Urbana-Champaign Office for the Protection of Research Subjects (Protocol Number 22028). All participants were informed about the study and provided consent before being interviewed.

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COMPETING INTERESTS

The authors have no competing interests to declare.

AUTHOR CONTRIBUTIONS

Both authors contributed to the study conception and design. Lauren Lynch facilitated trainings for community scientists, conducted and transcribed interviews, and analyzed the data. The first draft of the manuscript was written by Lauren Lynch, and James Miller commented on and revised previous versions of the manuscript. Both authors read and approved the final manuscript.

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