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Transference of Citizen Science Program Impacts: A Theory Grounded in Public Participation in Scientific Research

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Abstract: Citizen science is known for increasing the geographic, spatial, and temporal scale from which scientists can gather data. It is championed for its potential to provide experiential learning opportunities to the public. Documentation of educational outcomes and benefits for citizen scientists continues to grow. This study proposes an added benefit of these collaborations: the transference of program impacts to individuals outside of the program. The experiences of fifteen citizen scientists in entomology citizen science programs were analyzed using a constructivist grounded theory methodology. We propose the substantive-level theory of transference to describe the social process by which the educational and attitudinal impacts intended by program leaders for the program participants are filtered by citizen scientists and transferred to others. This process involves individual and external phases, each with associated actions. Transference occurred in participants who had maintained a long-term interest in nature, joined a citizen science program, shared science knowledge and experiences, acquired an expert role to others, and influenced change in others. Transference has implications for how citizen scientists are perceived by professional communities, understanding of the broader impacts and contributions of citizen science to wicked problems, program evaluation, and the design of these programs as informal science education opportunities.

Keywords: citizen science; transference; wicked problems; insect conservation; evaluation; program impacts

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1. Introduction

Citizen science is a research relationship between professional scientists and the general public or non-credentialed individuals [1,2]. It bridges communication between the scientific community and the general public about contemporary science topics and environmental issues [3]. The combination of public participation, educational outreach, and research is intended to generate educational and scientific benefits for all involved. Citizen science-generated data have allowed researchers to publish in peer reviewed journals on conservation issues in the fields of entomology [4–12], mammalogy [13,14], marine studies [15,16], urban wildlife conservation [17], and ornithology [18,19]. At a global scale, the potential of this volunteer-driven data has been recognized for tracking the progress of the wicked problems reflected in the United Nations Sustainable Development Goals (SDGs), including biodiversity and conservation goals [20,21]. However, while data are critical for understanding and protecting biodiversity, scientists cannot resolve wicked problems associated with biodiversity conservation by themselves. Wicked problems benefit from communication between various stakeholders [22], and the increased interaction between the public and researchers afforded by citizen science provides an educational and experiential opportunity for multiple stakeholders to reflect upon and learn about wicked problems [23]. Amidst this opportunity to cultivate a public understanding of science and environmental issues, the popularity of citizen science has exploded due to its contributory value to the research of scientists [24]. As practitioners continue to validate the contributions of citizen science as a field in its own right, researchers have increasingly sought to substantiate the educational potential of these programs for volunteers, now present in formal education at all levels [25–32]. The aim of this paper is to show how a pollinator conservation citizen science program provided an educational and experiential opportunity for volunteers to engage with a conservation issue and, perhaps more importantly, put the volunteers themselves in a position to raise awareness of and influence behavioral changes regarding pollinator conservation in their social spheres. This phenomenon may be leveraged by citizen science program leaders and conservation practitioners as a means of expanding awareness about conservation issues.

1.1. Capturing the Educational Outcomes of Citizen Science

The educational outcomes of citizen science have been aligned with experiential education [27,33,34] and free-choice learning [35,36]. Experiential learning theory has been conceptualized in a variety of ways and is deemed to be a prominent learning method in adulthood [37,38]. Whether for students or senior citizens, the authenticity of citizen science is believed to provide numerous benefits and influences upon participants, including increased scientific literacy, understanding of the nature of science and scientific process, increasing engagement in environmental policy decisions, pro-environmental behaviors, community engagement, and increasing logical debate and decision-making skills for handling scientific, social, and political issues [1,3,28,39–46]. Knowledge gains afforded by citizen science efforts have been identified as a path to increase public engagement, inputs, and decision-making for conservation, natural resource management, and environmental protection efforts [47]. Educational and science literacy gains from citizen science have been attributed to the experiential nature of programs, the collaborative interaction between participants and credentialed experts, the provision of high-quality educational materials, and legitimate contributions to research [3]. Studies have investigated the influences of these programs on citizen scientists both in and outside of the classroom and with various age groups. Trumbull et al. [48] concluded that citizen science provided a forum for scientific thinking, though the authors could not claim that their ornithology program itself caused scientific thinking. Alternatively, Jordan et al. [49] found no statistically significant change in the participants' understanding of the scientific process. The project-related knowledge that citizen scientists have has been found to increase following participation in some projects [33,50,51], while remaining the same after others [52,53]. Researchers have suggested that to detect knowledge gains in already motivated and environmentally aware citizen scientists, more sensitive and contextually appropriate instruments are required [33,50]. Program influences on attitudes and behaviors have also uncovered varied results. The attitudes of citizen scientists towards science increased [36] or remained the same [33] following participation in different projects. Evans et al. [51] found that a majority of their participants made accommodations for birds in their landscape, and Overdevest et al. [53] linked participation in their stream monitoring program to a significant increase in political participation. Alternatively, Druschke and Seltzer [52] reported that, despite their efforts, participation in their pollinator citizen science project did not promote changes in behaviors towards bees or inspire participants to learn more about bees.

While there may be mixed outcomes of the impact of citizen science programs on the knowledge and attitudes of the participants, social and community-centered influences have been detected. Researchers have found that participation in citizen science positively influenced the personal networks of the volunteers involved, the perception of community connectedness, project-related social interactions [51,53], and encouraged student classroom participation and family engagement in learning [29]. A broader influence was particularly evident in research on the outcomes of the Climate Change and Caterpillars project [25], in which the authors qualitatively detected positive behavioral and attitudinal shifts in the students of teachers who were participating in their project. Similarly, Forrester et al. [54] discovered that the volunteers in their mammal conservation project shared conservation information with their social networks.

1.2. Uncovering the Broader Impacts of Citizen Science through Qualitative Methods

Mixed research findings on the educational benefits of citizen science programs have resulted in an unclear understanding of how citizen science influences its volunteers. These studies further imply that social and educational phenomenon, outside the margins of experiential learning theory and beyond volunteers themselves, are at play. Considering that citizen science programs operate throughout a diversity of educational environments, audiences, cultures, and fields of study, an exploratory question arises: if experiential learning theory has not definitively explained citizen scientist participation, what educational experiences and activities are encountered by citizen scientists? The social nature of citizen science and its motivated participants suggests the possibility of broader program impacts, reaching beyond the citizen scientists themselves. These impacts are of particular interest because they represent an unchartered area and a mutually beneficial outcome of citizen science for program leaders and participants. The influence that citizen scientists may have on their community may be the more enduring and decisive influence of these programs. Qualitative research generates rich, descriptive data and is best employed to explore a complex issue and identify variables that cannot be easily measured when statistical methods do not fit the problem and when there is no theory to explain or describe a phenomenon [55,56]. Studies that have employed purely qualitative data to explore citizen science have focused on evidence of scientific thinking in participants [48], scientist experiences with citizen science [57], and teacher perspectives on citizen science outcomes in the classroom [58]. However, there is little research available to adequately explain the process of participation by adult citizen scientists and whether their experiences are represented by experiential learning theory. Grounded theory generates a theoretical explanation of an action, interaction, or process shared by specific individuals. This research was guided by the interpretive approach of constructivist grounded theory methodologies [59–61] to investigate how adult citizen scientists participate in and are influenced by entomology citizen science. This was primarily accomplished through collecting interview data, making multiple field visits, developing and interrelating categories of information, and creating a context-specific substantive theory [56,57,61].

2. Materials and Methods

In this study, we further explore the broader impacts of citizen science by focusing on program influences through citizen scientists, rather than on them. We introduce grounded theory methodology and provide a theoretical explanation of the broader outcomes of citizen science based on the experiences of adult volunteers participating in Bumble Boosters, an entomology citizen science program. Finally, we document and describe the social interactions of citizen science programs that should be considered when assessing the value of these programs.

2.1. Research Questions

This study explored the following questions to understand the broader impacts of citizen science:

1. How do adults take on the role of a citizen scientist in entomology research?
2. How do adult citizen scientists participate in entomology research?
3. How do adult citizen scientists perceive their role in entomology research?
4. How do adult citizen scientists share their science experiences with others?

2.2. Bumble Boosters: An Entomology Citizen Science Experience

We focused on adult citizen scientists volunteering in the "Building a Better Bumble Bee Domicile Project", a contributory citizen science project within the Bumble Boosters program run by the University of Nebraska-Lincoln's Department of Entomology. The project was initiated by D. Golick with a Kickstarter funding campaign and coordinated in collaboration with L. Lynch-O'Brien. Over the course of three years (2013–2016), citizen scientists throughout North America worked with us to test the efficacy of an artificial bumble bee domicile in attracting wild, nest-seeking bumble bee queens in the spring. A successful bumble bee domicile has been long sought after to support agriculture and conservation efforts, but most designs have had limited success [62–66]. This project represents a long-term research problem, and we commenced research to develop a new bumble bee domicile design based on entomological literature as well as the experiences of citizen scientists who were actively testing their own designs.

Citizen scientists received a project kit consisting of an experimental bumble bee domicile and pollinator conservation resources. Citizen scientists were encouraged to read the kit's written resources and to experiment with and modify their bumble bee domicile per a list of suggestions taken from the literature. They were then asked to place the bumble bee domicile on their property in the late winter and check for evidence of bumble bee occupancies each spring over the course of the three years. Annual reports were requested for information about the location and habitat surrounding the domicile, modifications they made to it, the presence or absence of bumble bees or other creatures inside the domicile, and a photograph of the domicile. Over the course of the project, participants engaged with the research program leaders through email and Facebook.

2.3. Sampling Procedures and Interviews

Several sampling methods were used during this study, including criterion, convenience, theoretical, and snowball (participant driven) sampling. Criterion (purposeful) and convenience sampling methods [56,67] were used to collect detailed information from individuals that was representative of entomology citizen science programs. Sampling criteria targeted adults (age 19 years or older) that had turned in at least one year's worth of project data to the Building a Better Bumble Bee Domicile citizen science project. Of 167 Bumble Boosters participants, a pool of 63 individuals met the inclusion criteria. Six individuals from this pool consented to an initial interview, three of whom also consented to a follow up interview approximately 14 months later. Theoretical sampling was employed to develop tentative conceptual categories [60,61,68] and compare the experiences of the entomology citizen scientists outside of the Bumble Boosters program. During the theoretical sampling phase, 9 citizen scientists were recruited for a parallel mixed methods study [69] representing the following programs: the Asian Longhorned Beetle Swimming Pool Survey, Backyard Bark Beetles, Firefly Watch, the Lost Ladybug Project, Milkweed Watch, and the Pieris Project. Aggregated demographic data for the 15 citizen scientists are presented in Table 1 below. A table with each participant's unique demographic characteristics is not included in order to avoid deductive disclosure [70].

Table 1. Aggregated demographic data of research participants (*n* = 15).

Category	Characteristics
Number of citizen science projects in which individual participates	1 project (10) 2 projects (3) 3 projects (1) 6 projects (1)
Age (Years)	33–67 Ave 52.7 years
Sex	Female (11) Male (4)
Highest level of formal education	Some college (2) Bachelor's Degree (6) Master's Degree (5) Doctoral Degree (2)
Previous employment as scientist, researcher or science educator	Yes (3) No (12)
Ethnic background	White/European American (15)
Aliases	Anne [1,12], Barbara [5], Bethany [4], Carolyn [1,5,8,9,10,11], Carlton [1], Charlie [4], Constance [6,13], Ellen [1], Joann [6], Katherine [1], Lois [1], Nance [6,10], Sean [3,5,7], Tom [2], Vicki [4]
Interview Duration (h:min:s)	00:14:26–00:58:49 Ave 00:31:07

[1] Bumble Boosters participant, [2] Asian Longhorned Beetle Swimming Pool Survey participant, [3] Backyard Bark Beetles participant, [4] Firefly Watch participant, [5] Lost Ladybug Project participant, [6] Milkweed Watch participant, [7] Pieris Project participant, [8] Aphid and Ladybug study participant, [9] State bumble bee survey participant, [10] Monarch Watch participant, [11] Journey North participant, [12] Project FeederWatch participant, [13] Tiger Beetle Project participant.

Snowball, or participant driven, sampling focused on the experiences of the individuals who had been influenced by Bumble Boosters citizen scientists. Bumble Boosters citizen scientists referred us to 4 non-citizen scientists with whom they had interacted. Interviews with these referrals allowed us to validate and further explore their interactions with the citizen scientists and their impacts on the people around them.

One-on-one structured interviews were conducted over the telephone, and audio responses were recorded with a digital voice recorder. Interview questions were developed to explore the experiences of the research participants in the Bumble Boosters program and focused broadly on an individual's decision to join, their role in the project, how they felt they benefitted from the program, and whether and how they shared the project with others. The interview protocol, including the interview questions, demographic survey, and consent forms for both the citizen scientists and the individuals within their social circles are available in the Supplementary Materials.

2.4. Triangulation and Theoretical Saturation

We verified the validity of interview statements regarding events, places, and activities by cross-referencing the information online or requesting documentation where applicable. We cross-checked earlier interview statements with those made in follow-up interviews or participant driven interviews. Interviews and triangulation generated additional data and extant documents that illustrated the actions of the research participants, and in some cases, also generated new codes (Table 2). A total of 170 artifacts were gathered, including websites, lesson plans, Facebook posts, photographs, physical artifacts (domiciles), entomology data submitted to citizen science programs, education awards and grants, publications by the research participants, outreach events, newspaper articles, documents from other citizen science programs, and blog posts. A graphic illustrating the phases of data collection and sources for an interviewee is provided in the Supplementary Files.

Table 2. Sampling types, methods and data sources utilized to generate codes.

Sampling/Method	Data Source	Data Generated
Criterion and purposeful sampling	Bumble Boosters participants that submitted year one data and were 19+ years of age	6 interviews
Follow-up interviews	Initial interviewees that submitted year two data	3 interviews
Snowball sampling	Individuals mentioned in Bumble Boosters interviews	4 interviews
Theoretical sampling	Citizen scientists from non-Bumble Boosters entomology projects [1]	9 interviews
Demographic survey	Citizen scientist interviews above (excludes Snowball participants)	15 surveys
Artifacts	Submitted citizen science project data, photographs of objects or activities related to citizen science, emails and text messages, Facebook posts, educational documents, newspaper articles, blog posts, other documents related to citizen science participation	170 documents Range per participant: 15–43
Initial coding	Interviewee transcripts	593 initial codes Range per transcript: 52–197

[1] Citizen scientists from entomology citizen science programs included in authors' mixed methods study. The authors of [69] provided transcripts for the theoretical sampling stage of this study.

2.5. Data Analysis

Non-verbatim transcripts served as the primary data source for this study and generated the majority of the codes. As is characteristic of grounded theory, data collection occurred in an iterative fashion with data analysis. MAXQDA 12 software (VERBI Software-Consult-Sozialforschung GmbH, Berlin, Germany) facilitated data analysis and visualization. All documents were stripped of personally identifiable information.

Coding. Initial coding in grounded theory is distinguished by being bottom-up, wherein codes are developed from the data, applied at a detailed level, and are not deductively based on literature [60,71]. Gerunds were used during the initial, line-by-line coding of the transcripts and artifacts to ensure that analysis focused on actions taken by citizen scientists. The number of initial codes per transcript ranged from 52 to 197 (total of 593 codes) and correlated with interview duration. Using MAXQDA's Creative Coding feature, similar codes were clustered together, named as a group (potential focused codes), and then organized into a hierarchy. Cyclical coding sessions resulted in tentative categories containing parent codes, each with subcodes. Within this group, similar codes were clustered together. Finally, codes were linked within the Creative Coding session to create a hierarchy for the tentative category, which contained parent codes, each with subcodes. Creative coding and memo writing produced several conceptual categories. The analysis of the research participant experiences was coded and color coded (see Section 2.6 Data Visualization) within ten conceptual categories. A total of five of these categories are the focus of this research, as they were most closely tied to the social relationships and influences that the research participants could have on those in their social circles. Descriptions of the additional conceptual categories are available in Lynch [72].

Data Validation. We established standards of validation through triangulation and the use of multiple data collection strategies, peer review, prolonged engagement with the participants, and member checking [55]. Following interview transcription, we corroborated evidence by requesting it directly from the research participants or acquiring the information from different sources and comparing events with additional interviews through snowball sampling. Finally, we provided rich, thick descriptions, calling directly upon the research participant's words and provided details when describing focused codes, tentative categories, and memos.

Memo writing. Focused codes were defined and explored during early memo writing, through which significant and frequent initial codes were explained, and the processes voiced by research participants were explored. Advanced memo writing developed relationships between significant codes, generated tentative categories, and finally, established theoretical categories.

2.6. Data Visualization

The use of visual devices helps to envision, grasp, and summarize the complexities of qualitative data [73]. Data visualization tools in MAXQDA 12 were integral to uncovering connections between conceptual categories and summarizing the individual experiences of different citizen scientists. Each conceptual category was assigned a unique color in MAXQDA. Using the "Document Portrait" tool, the progression, sequence, and association of specific codes in individual interviews was visualized and uncovered through color (Figure 1). Portraits "read" from top to bottom and left to right, just as lines are read in a book, aid in visualizing the presence, as well as the absence, of theoretical categories in an interview. This "painted" view of each interview facilitated data analysis and allowed patterns to emerge. Color frequency portraits, which are similar to bar graphs, illustrated which categories dominated a research participant's experience. Following early data analysis, ten conceptual categories emerged, as pictured below in Figure 1. However, five of these categories are the focus of this research. See Lynch [72] for descriptions of the other conceptual categories.

Color		**Conceptual Category**
Light green		Maintaining a long-term interest in nature *
Brown		Tempering fear of insects
Orange		Following citizen scientist protocol
Yellow		Thinking and acting scientifically
Dark green		Experiencing internal impacts
Purple		Barreling of citizen science and learning
Pink		Sharing science knowledge and experiences *
Dark blue		Attributing expertise to a citizen scientist *
Light blue		Assuming the role of expert *
Red		Influencing change in others *
Gray		*Interviewer questions*

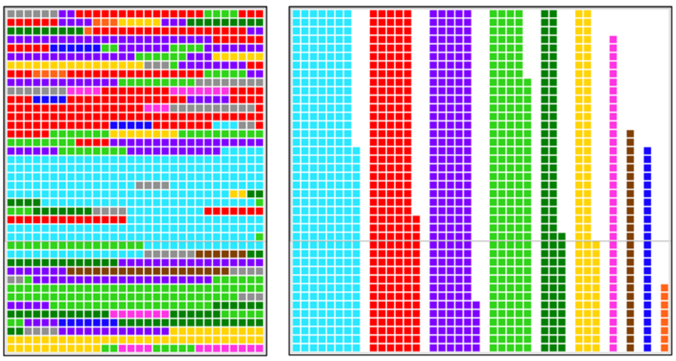

Figure 1. An example of document and color frequency portraits [MAXQDA 12] generated for each interview. * Those conceptual categories with an asterisk are the focus of this research, as they were the most closely tied to the social relationships and influences that the research participants could have on those in their social circles. Descriptions of the additional conceptual categories are available in Lynch [72].

3. Results

Grounded theory methodologies can generate two types of theory. The first, substantive theory, is a lower-level, theoretical explanation that is context-specific and does not attempt to generalize across several areas of study [60,68,71]. The second, formal theories, are less common, higher-level theories that offer a theoretical explanation of a sociological inquiry and generalize across many areas of study, partly through substantial theoretical sampling [60,68,71]. We propose a substantive-level theory illustrating how adult citizen scientists involved in entomology research influenced the attitudes towards insects, entomological knowledge, and pro-environmental behaviors of the people within their social spheres. We propose the term "transference" as a theoretical construct to explain the social process by which the educational and attitudinal impacts intended by program leaders for the program participants are filtered by citizen scientists and transferred to others. A total of five conceptual categories that were closely tied to the social relationships and influences that the research participants could have on those in their social circles arose from the experiences shared by participants during interviews and their analysis. For an individual citizen scientist, transference involves individual and external phases, each with associated actions (Figure 2). Individual actions are personal to each citizen scientist and include maintaining a long-term interest in nature, joining a citizen science program, and sharing science knowledge and experiences with others. External actions are driven by people within a citizen scientist's social sphere and involve expertise being attributed to a citizen scientist by others, acquiring the role of expert, and influencing change in others. Descriptions of each conceptual category, supporting data, and representative quotes are provided in Table 3. An expanded table, including additional representative quotes, is provided in the Supplementary Files.

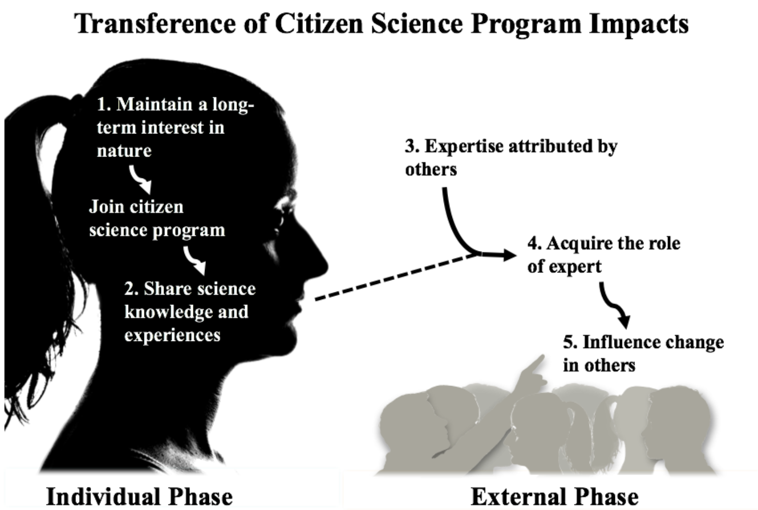

Figure 2. Several individual and external actions must occur for transference of citizen science program impacts to be achieved.

Table 3. Conceptual categories (actions) of transference with supporting data, artifacts, and representative quotes. An expanded table is provided in the Supplementary Files.

Conceptual Category **Description**	**Supporting Data and Artifacts** **Representative Quote**
1. Maintain a long-term interest in nature Refers to pre-existing and long-term affinity with nature or science that is an individual's source for joining a citizen science program. All interviewees associated their decision to join a citizen science program with their existing affinity for nature or science, enjoyment in learning about science, and using citizen science programs as a means of maintaining this interest.	**Participant experiences and recollections; participation in citizen science programs; nature journaling, photography, and other written records such as maps and newspaper articles** "[Appreciation for nature and science] just comes naturally from when I was young, at least part of it. Over my lifetime, I just was interested in it, so I pursued out of curiosity and fun".
2. Share science knowledge and experience Refers to the internal action of sharing project-related science knowledge and experiences with someone not involved in the project, including family members, neighbors, friends, colleagues at work, even acquaintances and strangers. All research participants described this action.	**Participant experiences and recollections; corroborating stories of individuals; social media posts; public programs given; classroom curricula and lessons developed** " . . . I do feel like my knowledge, I need to share it... I want people to know what [bee diversity] we have, and what is disappearing . . . Because if we don't [know], then when it disappears no one will ever know. It won't matter!"
3. Expertise attributed by others Refers to the external perceptions of individuals within a citizen scientists' social sphere in which citizen scientists are seen as experts due to their long-term interest in nature, their habit of connecting with people, sharing science knowledge and experiences, their involvement in and connection to current research, and certain qualities displayed in their interactions with others.	**Participant experiences and recollections; speaker invitations, participant statements, and perceptions from individuals within research participant social circles (snowball sampling)** "I would consider her an expert because she knows. She can tell you everything. Compared to anybody else I know".
4. Acquire the role of expert Refers to the phenomenon in which citizen scientists who are viewed as experts to those around them are called upon by their peers to answer questions about science, support learning about science and insects, and handle interactions with living organisms.	**Participant experiences and recollections; recollections and perceptions from individuals within research participant social circles (snowball sampling), conservation education awards received, and educational programming at public venues** "I'm considered their entomologist [laughter] . . . now they'll say, 'Go talk to Carolyn. Go ask her, she'll know.' So they see me as a kind of a bug, a bird expert".
5. Influence change in others Refers to the occurrence of social interactions through which research participants felt they had increased others awareness of interest in and attitudes towards insects, pollinators, and data collection for citizen science projects. This action also refers to incidents in which research participants described influencing conservation behaviors in others outside of the citizen science program.	**Participant experiences and recollections; recollections and perceptions from individuals within research participant social circles (snowball sampling)** " . . . [She teaches] it with such enthusiasm . . . she gets a response from the kids . . . I know they were interested. She had my attention. She said she always had something new every summer to show, so they said, 'Oh, please come back so we can see what you have next year'".

3.1. Individual Phase of Transference

3.1.1. Action 1. Maintain a Long-Term Interest in Nature

Maintaining a long-term interest in nature refers to the pre-existing and long-term affinity with nature or science that is an individual's source for joining a citizen science program. Participants enjoyed a physical closeness and interaction with nature and emphasized enjoyment in learning about science and making observations during participation. This interaction could be as simple as making and enjoying casual observations. More committed interactions were made by recording observations through journals (Anne, Katherine), through photography (Carolyn), or other written records, such as maps (Carlton). All interviewees associated their decision to join a citizen science program with this existing affinity with nature or science, enjoyment in learning about science, and using citizen science programs as a means of maintaining this long-term interest. They affirmed that their interest in nature was "always" there and was connected to their youth, recalling childhood memories of collecting butterflies, exploring natural areas with siblings, and being fascinated by animals and living things. This interest was often encouraged by parents, as in Nance's case, but can spawn from or be renewed by the curiosity of an individual's own children, as was the case with Anne, Sean, and Vicki. Several described themselves as being "all science", or "all about nature", and being known as a "nature enthusiast" amongst friends and family.

Considering the participants' long-term interest in nature, they expressed an enjoyment in learning about science. They explained that the opportunity to help add to and impact current research efforts was what they enjoyed the most about citizen science. Several interviewees described their citizen science pursuits as "getting involved at a higher level". This in vivo phrase encapsulates the enjoyment, excitement, and invigoration that the participants expressed about the usefulness of their participation in citizen science, the novelty and authenticity of the research, and their ability to impact science at an academic and policy level. Research participants felt that they were doing something useful with their interests by adding to the foundational knowledge of bumble bee research rather than, as noted by Carlton, "just casually observing something". Anne enjoyed the inclusionary nature of citizen science that allowed her to contribute to science research despite her non-research background. It was not only non-academic citizen scientists that expressed the enjoyment of participating in academic research. Barbara, a career scientist, intimated that she sometimes feels that she has more impact through the data she collects for citizen science than through the data that she obtains for her own work.

The research participants connected their enjoyment of learning science to maintaining their long-term interests in nature and science. They described the act of learning about science with excitement, enjoyment, surprise, and discovery. Citizen science provided an opportunity for individuals with a science background to remain connected to current research. Sean, an IT specialist with a master's degree in the sciences, expressed satisfaction in being able to stay involved with science through citizen science. All research participants detailed a long-term interest in building knowledge, an enjoyment in learning science, and gratification in their ability to interact with and support current academic research that could impact the future. As an internal action, their desire to maintain a long-term interest in nature led them to voluntarily join, interact with, learn about, and share their entomology citizen science program of choice. Thus, citizen science is one way for them to maintain their interests in science and nature.

3.1.2. Action 2. Share Science Knowledge and Experiences

Sharing science knowledge and experiences refers to the internal action of sharing project-related science knowledge and experiences with someone not involved in the project, including family members, neighbors, friends, colleagues at work, or even acquaintances and strangers. This action was described by all interviewees. Research participants shared science knowledge about insect diversity and identification, conservation and stewardship, pollinator importance, and pollinator friendly plants. Citizen scientists shared science experiences related to their personal interests, their experiences as a citizen scientist, their involvement in Bumble Boosters, and their methods for learning more about nature.

Casual encounters involved chance meetings and conversations in which interviewees shared information about the Bumble Boosters program or science knowledge and experiences. Interviewees explained that people tended to be surprised, even shocked, at the idea of their involvement in a bumble bee citizen science project yet, these same people discussed and wanted to know more about the project at length. Through these casual encounters, citizen scientists encouraged family members, neighbors, and friends to grow pollinator-friendly plants (Carlton, Katherine), encouraged children to interact with nature (Katherine, Lois, Carolyn, Anne), and alerted coworkers, friends, and acquaintances about citizen science (Katherine, Lois, Carolyn, Anne).

Some individuals explicitly described why it was important for them to share their science experiences and knowledge. Katherine, Carolyn, Anne, and Nance described their feeling of a need to influence people's attitudes towards nature and to share science. Carolyn, Anne, and Nance are, or were, teachers at the K-12 or postsecondary levels. Additionally, Carolyn is involved in teaching Master Naturalists. Throughout their careers, they have incorporated citizen science into their classrooms to varying degrees. They recognized that unique learning opportunities can present themselves with citizen science and that learning occurs over time and not only in the classroom. For example, Nance and Anne valued the authenticity of citizen science and the opportunity to connect citizen science research to their students' everyday experiences. Several individuals felt value in their ability to impact the awareness of bee diversity or science of others.

Based on interview statements by the six Bumble Boosters research participants, an estimate was developed to assess the potential number of individuals with whom a research participant had shared citizen science, and science knowledge and experiences. For a general statement indicating that a research participant discussed the project with people (plural), the potential number of individuals reached was counted as 2 because a more specific number could not verifiably be estimated. Where more explicit numbers were provided by a research participant, such as "we had about 50 visitors", the potential number of individuals reached was counted as 50. Although social media posts were used as secondary data and served as examples of communications by research participants, the level of potential individuals reached and the value of this interaction are difficult to ascertain; thus, these were only given a count of one potential individual reached. The six individuals varied greatly in the potential number of individuals with whom they shared citizen science, and science knowledge and experiences, ranging from 2 to 1258. Between family members, friends, neighbors, coworkers, students, social media posts, and encounters with acquaintances, these interactions totaled a potential 1315 individuals. Source quotes for the potential contacts reached are provided in the Supplementary Materials. This represents a potential number of individuals exposed to a citizen scientists' science knowledge and experiences, not the number of individuals upon which program impacts have been transferred. This illustrates the larger social reach of citizen scientists compared to program leaders as well as the expansive potential for transference through just a few Bumble Boosters participants.

3.2. External Phase of Transference

3.2.1. Action 3. Expertise Attributed by Others

The attribution of expertise to citizen scientists by others refers to the external perceptions of individuals within a citizen scientists' social sphere. The research participants who were interviewed in this study did not self-identify as experts. Others around them saw them as experts due to their long-term interest in nature, their habit of connecting with people, sharing science knowledge and experiences, their involvement in and connection to current research, and certain qualities displayed in their interactions with others. Snowball sampling provided a unique opportunity to explore this process, which was explicitly detailed by Carolyn and Anne and was evident in Carlton's interactions with a neighbor. They represent three of the six Bumble Boosters citizen scientists interviewed in this study. It was also present in the experiences of research participants from the theoretical sampling stage of this study—Nance and Vicki. Snowball sampling was pursued for all Bumble Boosters research participants; however, interview requests were only answered by individuals known to Carolyn and Carlton.

Paulette, Maggie, and Fannie are three individuals who witnessed Carolyn teach in various circumstances and, "without a doubt", considered her to be an expert. Paulette described Carolyn's ability to connect with students and witnessed her acting very naturally, photographing, teaching, sharing her knowledge, wanting to help other people lose their fear of insects, and appreciate diversity and the wonder of nature. Regarding her teaching, all three individuals shared that Carolyn's enthusiasm and science knowledge engaged and excited children and elicited questions from them during the programs. Each of these individuals witnessed Carolyn taking time to share her knowledge and passion with people and investing time, resources, and expertise. In a follow-up email, Paulette summed up her characterization of Carolyn: "She connects with all and is loved by all". It appears that failing to connect with others about the project may inhibit an individual from acquiring the role of expert. Ellen, for example, shared the project with family members but felt that she did not influence any changes in them, reporting that she did not observe any differences in their behaviors or attitudes towards bees.

Individuals also attributed expertise to a citizen scientist because of their connection to authentic research and professional scientists. A long-time friend of Carlton's shared his bumble bee findings with him because he is aware of Carlton's interest in bumble bees and wished to support Carlton's efforts with citizen science research. A citizen scientists' connection to professional researchers can benefit others as well. Maggie described how Carolyn's science knowledge and connection to research supports science education with other teachers: "She is very good at finding resources for us or ways that we can participate without having to spend a lot of extra money". This process is a significant discovery because it suggests that citizen scientists are far more than project volunteers. They serve as ambassadors for a project, increasing not only the geographic and temporal spans of data collection, but also the educational reach of a project.

3.2.2. Action 4. Acquire the Role of Expert

Acquiring the role of an expert refers to the phenomenon in which citizen scientists that are viewed as experts to those around them are called upon by their peers to answer questions about science, support learning about science and insects, and handle interactions with living organisms. In addition to participant experiences detailing how they are sought out by others, secondary data supporting this phenomenon includes awards received and educational programming at public venues. Several citizen scientists (Anne, Carlton, Carolyn, Nance, and Vicki) described how individuals within their social sphere knew them as experts. Research participants that acquired an expert role were similar in voicing resolute reasons of why it is important to share science experiences and knowledge. However, this intention alone did not precipitate an expert role. For example, Bethany, whose congregation hosted a Firefly Watch event, represents an individual who feels strongly about impacting others' awareness of insects. She explained, "[. . .] that's part of the mark I think [people of faith] need to leave in this world, is just an appreciation for all that God has given us". In her case, she is supportive of citizen science efforts on her congregation's property but did not describe taking on an expert role to the congregation members. Research participants expressed surprise at being considered an expert to their peers but were pleased and driven to share their knowledge and experiences. Carolyn described her role at school as an entomologist, "[. . .] a kind of a bug, a bird expert". Anne, who teaches mathematics rather than science, and Carolyn both described instances in which they were summoned by colleagues if an insect or other animal was found in or on school property. Thus, this role is not necessarily job-related. Teachers may become experts in science-related topics even though they are teaching an unrelated field.

Regardless of the expertise attributed by others, the research participants continue to distinguish themselves from the 'real' experts. Citizen scientists differentiate their participation from experts as a hobby and an activity for their spare time. Carolyn explained that science is a hobby for her and that she does not see herself as an expert. Despite being very committed in time, data, and resources, citizen scientists often see themselves in a supportive role. Carolyn decided to contribute her spare time, macrophotography expertise, and insect photographs to iNaturalist, Bumble Bee Watch, Bumble Boosters, etc. Her satisfaction in contributing to science grew—she has indeed started to become an expert in bumble bee identification and a champion for their conservation. Further, she is very conscious of her learning path to support these efforts. Upon reviewing the conceptual diagram of the grounded theory created by the authors, Anne reiterated, "the aspect that I feel least represents me is the role of expert. There is so much to learn, I barely scrape the surface". Tom did not see himself as a scientist, explaining, "I don't write any papers. I am not giving any speeches, writing any white papers or technical data on any of my field activities".

3.2.3. Action 5. Influence Change in Others

Influencing change in others refers to the occurrence of social interactions through which research participants felt they had increased others awareness of interest in and attitudes towards insects, pollinators, and data collection for citizen science projects. This action also refers to incidents in which research participants described influencing conservation behaviors in others outside of the citizen science program, such as the creation of a pollinator habitat and leaving pollinator nesting sites alone. Participants proposed that these outcomes were achieved by purposefully exposing people to positive experiences with insects to counter negative prior experiences. Carolyn set up positive experiences for students and also invited other teachers to help her and students collect lady beetles for a citizen science project. Carolyn has provided materials and encouragement to other science teachers in her area so that they, too, will bring citizen science into the classroom. Carlton purposefully promotes the usefulness of bees in pollination to his friends and neighbors. In one exemplary case, he discussed pollinator habitat problems with a neighbor looking to destroy a bumble bee nest. Carlton was able to convince the neighbor to leave the nest alone until the season had passed. Some citizen scientists promoted awareness and tolerance of pollinators by writing an article for a local journal, sharing posts on Facebook, and giving public presentations for Master Naturalists, local museums, and libraries. It should be noted that Carolyn and Anne, who showed the strongest evidence of assuming the role of expert to those around them, reached the greatest potential number of individuals.

Citizen scientists also reported bringing others into the research fold and achieved this in various ways. Citizen scientists carried out data collection in front of others, with the intention of showing them how easy it is and inspiring them to participate themselves. Nance noted that her students' focus strengthened once they began participating in citizen science because the data was to be used in actual science research. Carlton acquired permission from neighbors to place bumble bee domiciles on their property. These neighbors checked in with him as to the occupancy status of the domicile. Anne and Katherine used citizen science with their children during family time as a fun and educational activity. Anne even hooked her husband into participating in the Bumble Boosters program. Her husband later went on to submit a design to an annual bumble bee domicile competition, "The Bombicile Challenge".

4. Discussion

The qualitative methods of grounded theory provided a unique opportunity to explore and explain the actions of citizen scientists through their own experiences as well as those around them and to uncover a fuller understanding of how citizen science operates in the field. This study provides a theoretical explanation of how adult citizen scientists may acquire an expert role within their social spheres and potentially influence attitudes towards insects and science as well as conservation behaviors of people within their communities. This role may have implications for biodiversity conservation with regard to public engagement and participation in conservation efforts.

All research participants in this study viewed citizen science as a means to maintain their pre-existing interest in nature, sometimes in tandem with other nature- and science-focused activities, including nature journaling, nature photography, and researching science topics of interest through newspapers, popular articles, books, and training sessions. This aligns with research on the motivations of citizen scientists volunteering in biodiversity and environmental science projects [74]. Their motivation to join also stands to reason, as each of the research participants voluntarily joined their respective entomology projects. Further, as evidenced by the Bumble Boosters and other entomology project participants, citizen scientists may be professional scientists, professionals in other fields with a background in science, or self-taught naturalists. In addition, several of the research participants were active in multiple citizen science programs (Table 1). The Bumble Boosters program, as with many citizen science programs, has explicit goals to improve participant science literacy and public engagement in conservation—here, pollinator conservation. The participation of research participants in one or more citizen science programs to "maintain a long-term interest in nature" challenges the assumption that a program should or could greatly alter its voluntary participants' interest in science and the natural world. If the Bumble Boosters program, and perhaps other citizen science programs, serves as a beacon to bring together individuals already invested in pollinator conservation, what then happens to the program leaders' educational and conservation goals for the participants?

Certain aspects of transference bear a resemblance to the diffusion of innovation, a theory explaining how various technological innovations are adopted over time [75]. In this study, innovation pertains to pollinator conservation actions that an individual may take. Diffusion theory recognizes that effective communication between people about an innovation varies based on how similar individuals are in certain attributes, including beliefs, education, etc. Individuals with a strong degree of similarity in beliefs and background form a homophilous network and are able to share and communicate ideas more effectively and frequently [75]. Researchers and the citizen scientists that voluntarily collaborate with them meet the criteria for homophilous communication, forming a network based on shared interests in science, entomology, conservation, etc. While this relationship is important for supporting the learning interests and project objectives of citizen scientists, if global awareness about biodiversity is low [76] and diverse and broad stakeholder engagement is needed for society's ability to grapple with wicked issues [22], this homophilous network can limit the educational and conservation messages of the program leaders to individuals already interested in science and nature. Heterophilous communication, occurring between individuals with dissimilar attributes, is rarer and more difficult to engage in due to cognitive dissonance and conflicting positions but is more crucial in spreading new technological innovations [75]. When citizen scientists discuss a project with non-citizen scientists, they may be more likely to engage in heterophilous communication.

All of the research participants described the action of sharing project-related science knowledge and experiences with someone not involved in the project, including family members, neighbors, friends, colleagues at work, or even acquaintances and strangers. These casual encounters occurred regardless of whether the citizen scientist was seen as an expert by others. Although the authors could not verify the type of communication (homophilous or heterophilous) or determine the actual consequences of most of these encounters, the rough estimate of over a thousand potential individuals reached by the six Bumble Boosters participants (see Supplementary Files for source quotes used to determine this estimate) was difficult to dismiss. The Bumble Boosters program leaders committed sizable investments of time, money, and expertise to engage the public in pollinator conservation and were pleased with the number of funded project kits (167) and the associated project communications and outreach efforts with school-aged children and adults alike. Bumble Boosters participants that share their science knowledge, experiences, and efforts with pollinator conservation research added to the project's outreach efforts.

Although the research participants interviewed in this study did not self-identify as experts, some Bumble Boosters participants described instances in which individuals within their social sphere perceived them as such. Several of those interviewed were seen as experts in their home or workplace and as ambassadors of our program's educational and conservation objectives. Citizen scientists that have acquired an expert role exhibit characteristics resembling diffusion theory's opinion leaders and change agents. A change agent is an individual that possesses expertise in a given innovation and facilitates the adoption of the new idea in others. Much like people seek technological information from opinion leaders or people that they see as more technologically knowledgeable, individuals may seek out scientific knowledge and conservation actions from citizen scientists that they see as more scientifically knowledgeable. As citizen scientists participate in research, they may develop their own science knowledge and truly approach expertise.

Influencing change in others refers to the occurrence of social interactions through which research participants felt they had increased others' awareness of, interest in, and attitudes towards insects, pollinators, and data collection for citizen science projects. This includes incidents in which the research participants described influencing conservation behaviors in others and bringing others into the citizen science research fold by modelling project participation. Participants proposed that these outcomes were achieved by purposefully exposing people to positive experiences with insects to counter negative prior experiences. Hazen and Fox [25] described the indirect influence of a citizen science project through teachers who had joined their entomology research. Their cascading classroom is mirrored in transference, and we extend it to individuals outside of a classroom setting. Our findings align with social network and diffusion research on citizen scientists in India who also acted as environmental opinion leaders and who disseminated information and awareness surrounding environmental issues to non-participants [77]. These roles parallel a new perspective of citizen science as a community of civic educators. Ceccaroni, Bowser, and Brenton [78] define civic educators as individuals "who believe that providing information to others, and/or creating opportunities for others to learn, are paths to greater civic competence and a better future" [p. 2]. Research participants clearly reflected this belief, regardless of their level of entomology knowledge. Carolyn and Anne, who both acquired the role of an expert, shared a sentiment represented in a statement by Anne: "anything we do that makes somebody else aware of, or just opens someone to another issue or another attitude, is a good thing". According to Ceccaroni, Bowser, and Brenton [78], civic educators identify themselves as advocates, experts, or a combination of the two. Interview comments suggest that the individuals in this study would identify themselves solely as advocates. However, others have attributed the role of expert to them. Thus, citizen scientists may see themselves as advocates when they are indeed fulfilling an expert's role by educating the public and bringing them into the research fold.

Due to their geographic spread, science knowledge, positions as experts to peers, and opportunity for heterophilous communication, citizen scientists may have an advantage over program leaders in influencing educational and attitudinal change in the public. It is important to support citizen scientists as they acquire the role of advocate and/or expert. Each individual citizen scientist may influence biodiversity conservation efforts in their local, geographic community. This potential for diverse community and stakeholder involvement provides a crucial component of countering the wicked problem of biodiversity loss [76]. If program leaders consider communications, training, and/or materials that would support citizen scientists in this role, this might allow educational and behavioral impacts of a program to be spread through citizen scientists. For example, when speaking with citizen scientists about actions they can take to support insect conservation efforts, one of the authors (Lynch–O'Brien) explicitly encourages citizen scientists to share their project experiences with others in their social circles. It should be noted that challenges may be present in documenting and amplifying transference. The citizen science community may benefit from exploring the incorporation of diffusion theory principles into program design, volunteer training, and program evaluation to encourage heterophilous communication, measure broader impacts, maximize transference, and increase awareness of biodiversity conservation. By acknowledging that citizen scientists share their science knowledge and experiences, may acquire the role of expert, and have the potential to influence individuals within their social sphere, program leaders can prepare and preemptively capture, document, and leverage educational and conservation impacts reaching beyond the individuals in a program. This requires that citizen science program leaders collaborate with citizen scientists to engage new audiences in biodiversity conservation and request an invitation to chronicle the many methods and audiences reached by them.

Citizen science is recognized for its ability to expand the geographic, temporal, and spatial scales from which scientists can collect data in many disciplines, including biodiversity conservation. Citizen scientists become ambassadors of science and may expand the educational reach of a project. Citizen science is already contributing data to support our understanding of biodiversity and conservation at a global scale through the United Nations Sustainable Development Goals, including the monitoring of threatened species, the establishment of protected areas, and marine pollution [21]. Further, citizen science is positioned to contribute data to support the monitoring of all of the wicked problems reflected in the SDGs [20]. The conservation of invertebrate diversity, including bees and other insects, is impeded by negative perceptions towards these organisms, limited understanding of invertebrate ecological significance, and limited representation in conservation policies [79–81]. In particular, social interactions can influence how individuals respond to and value invertebrates [80] and science in general. Citizen scientists have been found to involve others and talk informally about conservation activities related to citizen science programming [82–84]. They have been identified as valuable guest speakers, field trip leaders, and partners in advocating for science in schools [85]. This has implications regarding how program outcomes are assessed, how to account for the broader impacts of citizen science, and how to leverage conservation-focused programs to counter biodiversity loss. Deliberative engagement, a collaborative approach to building community capacity and negotiating solutions to wicked problems, requires public communication and engagement [86]. Program leaders may wish to encourage and document these social networking pursuits as potential evidence of transference.

In this study, citizen scientists positively influenced attitudes towards science, attitudes towards bees, and the pro-environmental behaviors of others. We found that the science knowledge shared by citizen scientists with others is filtered by various elements, including their own science experiences, prior knowledge, expertise, local politics, etc. This may alter a citizen science program's intended educational conservation message when it is transferred by a citizen scientist. However, the anecdotal positive influence on the public through citizen scientists is still compelling and provides an avenue for improving stakeholder engagement in biodiversity conservation. The outreach capacity of citizen scientists is a metric that should be considered in measuring the success of a citizen science program; especially where citizen scientists already have positive attitudes towards science, nature, the environment, etc. In fact, the recently proposed dimensions of engagement framework [84] provides a new typology to characterize participant engagement that acknowledges the behavioral and social/project activities, among others, in which citizen scientists may engage. Transference supports this framework and adds to the list of outcomes of citizen science programs, representing an extension of researchers' educational outreach capacity through volunteers to communicate the importance of biodiversity conservation. Transference of program impacts and social interactions occurring through citizen scientists may provide a beacon to unite citizen scientists interested in nature. This, in turn, provides program leaders an opportunity to collaborate with citizen scientists to reach new audiences and build the diverse stakeholder engagement needed for society to begin taking on the wicked problem of biodiversity loss.

5. Limitations

As a qualitative study, the constructivist grounded theory methodology used in this research is not broadly generalizable to citizen science communities in terms of traditional quantitative generalizability. Additionally, the small number of research participants further decreases this quantitative generalizability. However, the findings are transferable to other similar settings and contribute an empirical understanding of transference. This study leverages the strengths of qualitative research by employing qualitative processes of triangulation, member checking, and providing rich, detailed descriptions of the shared actions of purposefully recruited participants. It employed the qualitative processes of triangulation, member checking, and theoretical saturation.

Self-selection bias is a limitation of this study. The recruitment of research participants from citizen science programs to conduct this research was challenging. Of the 167 Bumble Boosters participants, the six individuals recruited represent those who met the inclusion criteria and who were also willing to be interviewed. However, the theoretical sampling pulled in research participants from other entomology citizen science programs, primarily from local chapters initiated by one of the authors for the purpose of recruitment. These local chapters were initiated after attempts to connect with potential research participants through citizen science networks produced a limited number of interviewees. In addition, the research participants represented a narrow demographic profile.

Supplementary Materials: The following are available online at https://www.mdpi.com/article/10.3390/d13080339/s1, Figure S1: Color coding example, Figure S2: Transference illustration, Table S1: Demographic data of research participants, Video S1: 2014_Bumble_Boosters_Domicile_Design.mp4, File S1: Bumble Boosters Code Memo Workbook, File S2: Bumble Boosters Code Summary Grid.pdf, File S3: Bumble Boosters Document (Interview) Portraits.pdf, File S4: Creative coding sequence.png, File S5: Transference Individuals Estimate, File S6: Consent Forms, Interview Questions, and Demographic Surveys, File S7: Multiple data sources generated through interviews and triangulation, File S8: Source Quotes for Potential Contacts Reached, Table S2: Expanded Themes and Representative Quotes.

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