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Developing a Framework for Citizen Science: Preparing Researchers for Success

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DEVELOPING A FRAMEWORK FOR CITIZEN SCIENCE: PREPARING RESEARCHERS FOR SUCCESS

By

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CHAPTER ONE

Introduction

Citizen science is a field that has connected researchers and the public in ways that were previously unimaginable. Citizen science is a way to bridge the gap between education and active research, giving the public an opportunity to be a part of the research process and a part of science as a whole. Citizen science projects vary greatly in context and scope, varying in topics from astronomy to zoology, and involving local communities or classrooms. The opportunities possible in the field of education and crowdsourced research are unfathomable and will become a staple of many research projects in the future. Despite the growing nature of citizen science, there were few resources that provided a unified working framework around the diversity of projects; and even less understanding of the relationships between researchers and volunteers. The growing field of citizen science is at a crucial point at determining an identity for the future. Citizen science projects take on many different forms with varying success based on experience from individuals and educational knowledge. Many citizen science projects fail to start or progress beyond the first year due struggles between expectations and results. This leads to the research question: *What makes a citizen science project successful? How can a better understanding of the relationship and expectation between researchers and volunteers create greater success?*

The first chapter explores personal motivations and rationale behind the research question. I have been a part of multiple citizen science projects as a researcher, educator, and volunteer. Through these different roles, I have experienced the highs and lows of

citizen science and gained sufficient personal and professional experience to wonder what makes a citizen science project successful enough to bring to a national or global scale. Chapter one explores the rationale behind the research question and provides an overview of the paper as a whole.

Personal Experience

From my own experiences participating in citizen science projects as a volunteer, educator, and scientist, I had first hand experience with the failures and successes from beginning to end of varying citizen science projects. I was a lead scientist for a museum funded volunteer project. Within the role as a researcher, I had greater experience with the content knowledge compared to others who were recruited volunteers. From my background in geology, I was able to guide others on what to look for in the field and how to use proper paleontology tools (mostly dental equipment and mint tins) to extract fossils. Many of the volunteers involved in this paleontology project were experienced through previous lab work at the museum's paleontology lab, or had private experiences for fossil hunting in the western United States and did not need a broader introduction to paleontological methods, but instead had a desire for greater content knowledge on local fossils. Within my role as a lead scientist, I often felt inadequate in my own content and experience compared to some of the hobbyist volunteers, that while they may not have had the same formal teachings in academia as me, volunteers had years of knowledge with the same tasks through public and personal experiences. Lead scientists and volunteers had troubles communicating their expected experience from participating in the paleontological citizen science project. The volunteer base, at times, was better suited

to lead within the first year of this project compared to the researchers, and the frustration from volunteers for a curated experience became obvious.

During the first year of this project, there were few boundaries established between volunteers and researchers where both parties accomplished similar tasks and had similar educational backgrounds. Some members of the research team were not as well suited in their roles compared to more experienced volunteers. Regardless, the project gained public traction through local media, and many more people wanted to be involved as volunteers with less experience and scientific knowledge after public media reports on exciting fossil finds. It is also worth noting that both the researchers and volunteers were donating their time to the project, and there were no paid positions.

For the second year, lead researchers above my position decided to vet out volunteers with a "test" dig, requiring previously dedicated and experienced volunteers to reapply for their position. The project lead was hoping to free up some space for newly interested and less experienced volunteers instead of expanding the available team. Volunteers from the previous year found the test to be insulting given their lifelong experiences with fossil digs and weeklong dedications to all day digs (often taking vacation time at work) for specimens entering the museum collection. At this point, previous volunteers felt their desires for content knowledge and paleontology dig experience would be better suited through other organizations. New volunteers were interested in learning the scope of the project but lacked the same dedication and skill that hobbyists had, and would often call off trips or leave early leading to decreased participation despite the increase in interest by the public. This ultimately lead to less

data being collected, less accomplished on fossil dig days, and a lack of scientific integrity.

From the beginning of this project, there was a lack of communication between volunteer and scientist expectations and a lack of understanding from scientists to the volunteer base. The project was still considered to be an overall success in the eyes of the public, with educational outreach at the Department of Natural Resources through the Minnesota State Fair, and perceived success from the museum with the sheer number of fossils collected although no formal scientific papers were published. Once the public spotlight died down, so did the number of willing volunteers for the following years. The project failed to opportunize public successes and failed to retain dedicated and experienced volunteers.

I was also involved in a similar project as a volunteer across state borders for a paleontology dig for vertebrates across the Jurassic and Ice Age. I was excited for the opportunity to participate given my previous experience with fossil digs but had little content knowledge of the fossil beds that I would be experiencing. Like volunteers in my previous project, I was excited to gain new content knowledge and to use my previously obtained skills for fossil collecting. I was also motivated by the knowledge that my discoveries would enter the state collection, and potentially go on display at the North Dakota Heritage Center. I would spend dawn to dusk for days at a time in the desert sun carefully sifting through and brushing off dirt to find a Tyrannosaurus rex tooth or mouse jaw. Whenever I made a new find, I would consult one of the researchers to learn more about what prehistoric animal I just uncovered.

Throughout this experience, I spent time with local experts, learned about the fossils as I saw them, and collected useful prehistoric data for the state. Many of the larger finds were carefully extracted with plaster castings or wrapped up under tarps for the following year's dig to which I would have the pleasure of revisiting along with them. The scientists were eager to interact with the public, and welcoming to everyone from a variety of experiences. The scientists throughout the year would also update their volunteer base on 'cool dino facts' and when the volunteer collected fossils were used for taxonomy projects or projecting future finds. For volunteers that have participated for years, there was a sense of trust, and new volunteers were introduced to the history and process. Issues only began to arise when the program became more exclusive.

As the project grew bigger, many of the same volunteers would continue to take the spots of potential new volunteers leading to the same group of people arriving every year for the same experiences. There were still new participants that wanted to join from all over the United States that were denied the opportunity compared to already existing volunteers. As a result of demand, the scientists added a cost per day for participation from 5-90 US dollars. Considering there were similar led fossil digs where participants could keep their findings instead of giving them to the state for a similar price, the participation significantly decreased as a monetary barrier to participation was raised.

Other citizen science projects that I have participated in looked for willing and able volunteers to whack away invasive species in state parks, or observe an astronomical event using a personal telescope. Many citizen science projects also focus on educational outreach through activities or events but often ignored the volunteers that were most

dedicated to the project or left the results open ended. Following up with volunteers about your transforming project is crucial for continuous participation. From my own experiences and from hearing those around me, participation in citizen science felt lacking as a researcher, volunteer and educator. Citizens were engaged in data collection, or some analysis but were never recognized in scientific literature as a part of the process, or heard any follow-ups to the projects they were involved in without independently seeking more information. Researchers, volunteers and educators who were all invested in the success of citizen science projects failed to communicate their expectations with one another, leading to failed projects.

Research Question

This is where I wondered: *Why do citizen science projects fail? How can a better understanding of the relationship and expectation between researchers and volunteers create greater success?* From an educator and volunteer standpoint, I wanted to latch on to a project that is making a difference, and that I felt appreciated in participating. Researchers were not always effective communicators, although citizen science gave researchers an opportunity to speak to the public about their project. The lack of communication seemed to stem from a lack of educational incentives for researchers, leading to future failures even if a project gained initial traction (Pocock et al., 2017). Many citizen science projects fail to incorporate an educational component at all, and instead concentrate on crowdsourcing data with little follow up for those interested in seeing where the research is going (Pocock et al., 2017). By starting a citizen science

project, scientists need to forego their sense of ownership towards their research if it asks the public for participation.

What can be done to develop better communication between scientists and volunteers? If I had been prepared as a researcher, the paleontology project that I led could have seen greater public success and retained volunteers for years to come. Even though I am no longer involved in that project, finding new volunteers or creating interest without the help of public media and the Department of Natural Resources had become increasingly difficult. As a volunteer, I had a desire to learn about new content specific knowledge and to feel like I am contributing to active science research through my own specialized skills. As an educator, I wanted to experience the scientific process with the researchers and figure out how I can bring my experiences back to an educational setting to give students the same opportunities. Finding a balance between expectations from different roles can make or break the success of a citizen science project. Effective communication and education seemed to be at the root of understanding how citizen science projects can be successful.

Rationale

In order for the future of citizen science to reach greater success, the educational component cannot be ignored as a part of volunteer participation. Understanding the shortcomings of citizen science depends on observing researchers, their projects, and surveying volunteers. Education is a fundamental part of successful citizen science projects, but researchers do not always have a background or experience in education outside a university setting (Pocock et al., 2017). Projects that were perceived as

successful from participants incorporated education at the conception of the project; while projects that were focused solely on education usually had little scientific merit in science literature (Phillips et al., 2017).

The average participant for citizen science projects were well educated, white men over the age of 55 (Jones et al., 2018), leaving a large portion of citizens unrepresented in participation. An important piece for the future for citizen science is creating a more diverse and dedicated volunteer base. As citizen science projects shift towards mass participation with minimal required skill, the barriers for entry will be lower for citizens from all walks of life (Pocock et al., 2017). For active scientists to reach a wider array of citizens, communication needs to be clear and create a sense of community and ownership (Jones et al., 2018). By developing supportive content directed towards researchers and prepared by educators, citizen science projects can better serve participating volunteers and the rest of the public.

Chapter Overview

Chapter One focuses on my personal experiences with citizen science projects, and the problems I have seen as a participant in multiple lenses. I have participated in citizen science as a scientist, volunteer and educator. These roles often intertwined with one another, but each identity seeked a different experience from participating. The future of citizen science is reliant on growing interest and participation from the public, and well developed scientific inquiry from researchers. Communication between researchers, educators and volunteers is necessary for a successful citizen science project.

Chapter Two focuses on the academic literature surrounding citizen science, and the evolution of participation over time. Most of the literature focuses on how volunteers are motivated and participated, and the identity of a typical citizen science volunteer. Some of the research explored the role of citizen science in classrooms and models classrooms that focused on developing a project alongside researchers, while other projects were developed by researchers for volunteer participation. Chapter Two also explores where citizen science happens on a local and global scale, and how the identity of citizen science has been changing over time.

CHAPTER TWO

Literature Review

Citizen science is a collaborative movement between scientists and the public to answer research questions in ecology, biodiversity, astronomy and beyond (Price & Lee, 2013). Participants from the public help collect data through different mediums and specializations that ultimately go towards informing changes to policy or developing a greater understanding of our universe. Some projects have a higher barrier to entry for volunteers, or require scientist-led training before participation, in addition to time-intensive dedication on the part of volunteers. Understanding volunteer motivation to work on highly trained and dedicative projects is integral to successful citizen science projects (Kieslinger 2018). Many citizen science projects rely on engaged volunteers to succeed. Educators collaborate with scientists or lead citizen science projects to create a deeper understanding of the scientific method and specific content knowledge with lukewarm success (Roy et al., 2016). The goal for this capstone project was to work alongside scientists and volunteers to develop a working framework from the projects' conception and to have a fluidly usable educational curriculum to support researchers. By promoting a supportive community of researchers through an informative workshop, researchers will be given the tools to understand why their project is gaining traction or hitting a dead end.

There were certain qualities that all successful citizen science projects share, but the success of a project rides on expectations from a variety of stakeholders. A project may be successful in data collection according to scientists; but the volunteer experience

lacks educational understanding which increases content and methodology knowledge (Harjanne et al., 2015). To better understand where citizen science projects succeed, the project took under consideration different stakeholders and their motivations, where citizen science happens and what affects interactivity and participation, understanding the scientific implications and benefits of incorporating citizen science as a part of a project, and developing citizen science projects. Citizen science projects are becoming a regular part of many school curriculums and university funded ecological projects. If a strong motivational message can be created when the project is developed, the project is guaranteed for greater success (Bonney et al., 2009).

Citizen Science: Definition & Stakeholders

Citizen science projects involve people from diverse backgrounds and motivations. The focus of citizen science has changed over time to become more inclusive to volunteers of all skill levels, not just volunteers with special interests (Pocock et al., 2017). Participants can be involved from the conception of inquiries, to data collection and processing (Pascual et al., 2016). In order to understand what makes a citizen science project successful in the eyes of educators, scientists, and participants, there needs to be a greater understanding of individual motivations within each role. Many studies began research within these areas, especially when considering the volunteer or scientist experience, but there is little literature exploring the educational merits of citizen science (Phillips et al., 2018; Roy et al., 2016). Since citizen science is a still developing field of science, there is a need to balance the educational and scientific goals within any one project.

What is citizen science?

Citizen science is a difficult term to define in the greater context of scientific literature. In general, citizen science is described as a project led by one or more scientists that was built off of assistance from willing and interested volunteers to collect data and ultimately assist with research (Dhillon, 2017; Edwards, 2014; Jones et al., 2018). Participants vary in skill level and subject knowledge. Citizen science can take on multiple forms, from a local catch and release of butterflies after being tagged to online applications through crowdsourcing websites like Zooniverse, and from topics like classifying galaxies from Hubble Space Telescope data or megafauna on beaches (Harjanne, Ervasti, Karhu, & Tuomenvirta, 2015; Roy et al., 2016). Scientific content varied greatly with each proposed project, but some projects were met with greater success than others. Citizen science has been around for over 100 years but has only recently been utilized by scientists as a way to collect and sift through great amounts of data (Pocock et al., 2017).

Stakeholders

Within each citizen science project, there are different stakeholders to consider, and their expectations from participating within a project. Volunteers were described under multiple identities, being equally defined as citizen scientists, students, advocates, and hobbyists (Edwards, 2014; Jones et al., 2018). Citizen science projects are started by scientists seeking to engage the public in active research while recruiting assistance in data collection and processing. Volunteers serve many purposes from developing projects alongside scientists from a hypothesis and concluding research, to data

collection over years within the same location. The research collected was used by management and advocates to inform policy decisions or determine the effects of anthropogenic influences in natural areas (Toft et al., 2017). In order to understand what made a citizen science project successful from the position of a scientist, volunteer and educator, the motivations and expectations of different stakeholders need to be considered.

Scientists. Scientists act as starters for projects by developing a hypothesis or continuing research. For a scientist, the benefit of having volunteers available gave opportunities to discuss active research with an engaged public audience and collect reliable data over years or areas that would have been daunting with a small research team or impossible to process with a computer (Zooniverse, Harjanne et al., 2015). Scientists are experts within a project, and are sought out by volunteers to share their expertise and motivation. Scientists within the process of citizen science forego the right to privatize collected data, and instead make the data publicly available, or open source, for anyone to manipulate or interpret (Pettibone et al., 2017). Scientists are motivated in their research from a sense of inquiry and curiosity in the natural world or beyond, and guided by their greater content knowledge compared to the general public. The scientist role also benefits from being an impartial body within the study, where advocates or management may seek out results instead of accepting what is observed (Toft et al., 2017).

Scientists, alongside educators, develop ways to engage and maintain volunteers by making data collection accessible and easy to perform, and providing additional

motivation for volunteers through unique experiences or an understanding of the importance of scientific merit. Scientists are leaders in citizen science projects and a central focal point to understanding the successes and failure of citizen science.

Volunteers. Volunteers vary greatly in previous experience, passion and knowledge. The typical volunteer, as conducted through surveys by Jones, Childers, Andre, Corin, and Hate (2019), was around 55 years old, white, college-educated, and male from publically conducted projects. The lack of diversity in citizen science outside of school collaborations is a growing problem when trying to engage citizens in active research within a region. In most citizen science projects, participants do not reflect the community the project took place in although expanding diversity within citizen science has not been well researched. Volunteer skill levels and level of participation vary depending on the context of the project, and the expertise required. Two groups of volunteers that are heavily utilized and studied were astronomy and birding hobbyists, with projects in these subject areas receiving a large number of participants compared to biodiversity surveys (Edwards, 2014; Kieslinger et al., 2018; Price & Lee, 2013; Scroggins, 2017).

Volunteer participation was presented as anonymous for most scientific literature. If a specific hobbyist group was involved in data collection, their group would be acknowledged within the paper, but individual participants were never identified. Volunteers are motivated by a sense of civic duty, an opportunity to work alongside scientists in active research, and environmental or societal advocacy (Jones et al., 2018). Through one study by Edwards (2014) in their paper, *"*Citizen Science and Lifelong

Learning*"*, volunteers that participated in citizen science projects were more willing to share their content knowledge with other members of the public and participate in educational opportunities. Hobbyists involved in similar fields but who choose not to participate in citizen science projects were less likely to participate in social events and share their content knowledge with the public (Edwards, 2014).

Educators. When developing citizen science projects, education is traditionally treated as an afterthought instead of a part of the developing knowledge base. Volunteers were expected to do training before participating, with some training taking less than ten minutes, and other training taking ten or more hours (Toft et al., 2017). The training prepared volunteers to collect data, and provide a sense of ownership, importance and content knowledge in return for their participation. The training sessions are either led by scientists or from readable education material. Educators are essential for successful citizen science projects with many participants seeking opportunities to grow their knowledge of the scientific process and content knowledge. Citizen science projects that reached greater audiences were more successful because they developed educational content alongside research. Educators were scientists, or partners alongside scientists, in many of the most successful projects (Pocock et al., 2017).

Some research projects develope a working curriculum for classroom teachers, museum educators and nature centers. By developing educational content that works alongside active research, a more diverse group of volunteers can be reached. Educators were also informants to scientists on developing engaging content material, or scientist themselves.

Students & classroom participation. Citizen science projects that had a greater focus on education collaborated directly with teachers or school administration to create projects that reflect an active science curriculum (Scroggins, 2017). These citizen science projects focus on student learning as the main objective, and scientific inquiry as a secondary objective (Kermish-Allen, Peterman, Bevc 2017; Pettibone et al., 2017; Scroggins 2017). Students offer scientists an opportunity to interact with a more diverse population compared to hobbyist volunteers. Student participation is highly variable based on school locations (rural or urban), as well as ages (kindergarten through highschool) (Kermish-Allen et al., 2017). Schools in rural environments are easily able to adjust the curriculum to fit in citizen science projects, while urban schools struggle to add an additional project with an already packed curriculum, receiving district permission and other barriers to entry for teachers (Kermish-Allen et al., 2017). Citizen science projects that were most successful with classrooms in mind focused on developing a project alongside students from inquiry to conclusive data collection (Scroggins, 2017). These types of citizen science experiences provide little scientific merit but promote greater scientific literacy at all ages. Citizen science projects that collaborated with classrooms also had greater educational curriculums.

Students that participated in classroom citizen science projects were as involved as their teachers if approached with enthusiasm and inquiry (Kermish-Allen et al., 2017). Citizen science projects that heavily invested in classroom learning kept ongoing projects over two or more years with the same group of students as a full experience of the scientific method on an individual collaborative project (Scroggins 2017). Student

motivation and long term interest in science from participating in citizen science have not been measured or studied sufficiently. The values of incorporating citizen science as part of a school curriculum has not been explored in current literature.

Advocates. Advocates are present in the roles of scientists, volunteers, educators and management (Toft et al., 2017). Advocates are invested in seeing change to public policy as a result of their efforts in participation (Jones et al., 2018). Advocates show a lot of passion as volunteers and educators, but come at the cost of collecting accurate or usable data at times (Clare et al., 2019). Some advocates have unitientional implicit bias which can make unusable data into bad science (Scroggins 2017). Since advocates are found among all other roles in a citizen science project, this group is motivated by creating lasting social change through informed policies (Dhillon, 2017). Projects led by advocates has the potential to be biased or alternatively motivated, but will not change the data if the citizen science project is led to promote 'good' science practices.

Management & policy makers. Management and policy makers are motivated to make lasting social and ecological change based on citizen science research (Jones et al., 2018). Management plays a larger role in ecological citizen science projects, where volunteers take surveys to gain a deeper understanding of invasive species, biodiversity, water quality and health of the land. Citizen science projects inform policy for management at parks, cities and national platforms. Management and policy makers lean on research to make lasting changes that the community as a whole could support (Jones et al., 2018).

Connected roles. Between scientists, volunteers, educators, advocates and management, citizen science projects need to balance many different identities and motivations to find success. Many of these roles cross over where managers were also advocates, or volunteers that are also scientists (Toft et al., 2017). When roles are connected, motivations from one identity to another can overlap and create a more engaging experience for everyone and enhance participation and project results. Many of the roles that take place in a citizen science project are present through the same participants, whether the role is a scientist, volunteer, educator or anything in between.

Summary

There are many stakeholders to consider when developing and quantifying success for citizen science projects. Different stakeholders come into a project with separate motivations and identities that can affect the success of a project. Success for a citizen science project requires active participation, well-developed education content for volunteers, and action to be taken as a result of the project. With stakes in accurate data collection for scientists, engagement and community for volunteers, public facing educational merit for educators, creating change in public policy for advocates and management. While none of the stakeholders have a major conflict of interest within their motivations, there are many different points of success to account for within a citizen science project. These roles can inform what is expected from different people across a citizen science project, and help identify where the roles and motivations overlap. Misunderstanding motivations and identities can lead to failure in citizen

science projects, especially when volunteer expectations do not match with scientists motivations.

Where Citizen Science Happens

Citizen science happens at every level, from neighborhood projects to global discoveries. Where citizen science happens affects the participation and diversity of volunteers. Projects reach out to local neighborhoods to take action on active policy changes, or involve persons all across the globe in counting penguins (Dhillon 2017; Zooniverse, n.d.). Despite the range of possibilities for diverse participation, most volunteers were around 50 years old, well educated, and white (Jones et al., 2018). Citizen science projects are more involved in including volunteers in the research process when volunteers were recruited locally, compared to global projects (Pocock et al., 2017). From a location, a sense of community was built, leading to some volunteers to sharing their knowledge and experiences with family and friends, or continuing stewardship.

The rise of citizen science projects is attributed to the growth of large data sets in science that cannot be easily processed with computer modeling (Zooniverse, n.d.). In reality, citizen science has been a part of scientific literature for over 100 years, beginning with the Christmas Bird Migration Project in 1900 (Scroggins, 2017). The Christmas Bird Migration project started as an annual hunt to see aviary diversity, but has since evolved to a yearly bird watching event (Shroggins, 2017). The Christmas Bird Migration Project is ongoing as of 2020. When exploring where citizen science projects happen, time must be taken into consideration on equal importance with spatial

recognition (Pettebone 2017). Some projects took place over ten years within the same small locale beach area, while other projects explored galaxies far beyond and took advantage of increased global online accessibility to open up participation to everyone (Toft et al., 2017).

Local projects

The largest abundance of citizen science projects are conducted on local levels (Pocock et al., 2017). Localized citizen science projects benefit from participants that are intimately connected to the location in study. These projects asked for a few trusted and heavily invested volunteers for repeated participation. Local projects were more likely to lead to action or policy changes as a result of active participation and community dedication. Local projects are heavily focused on creating sustainable local changes through policy action, and rarely focus on the merits of scientific knowledge (Harjanne et al., 2015; Roy, Baxter, Saunders & Pocock 2016). Volunteers are intimately involved in local citizen science projects, and in some cases already had a great background of content knowledge before participation. Local projects succeed in building a sense of community and interest for like minded individuals invested in lifelong learning (Scroggins, 2017).

Classroom guided projects/co-created models

Classroom projects are citizen science projects developed alongside students to build science literacy and content specific knowledge as primary goals (Harjanne et al., 2015; Scroggins, 2017). Classroom guided projects are conducted at a local level and vary in content significantly, but with a greater focus on pollinators, invasive species and

other ecological quandaries (Harjanne et al., 2015). The most educationally successful local citizen science projects follow a co-created model, where students and staff were intimately involved in the scientific process from developing inquiries to publishing results (Price & Lee, 2013). Classroom guided projects are most successful with educational participatory goals in citizen science when students are involved from the beginning to end of a project; compared to jumping in on a continuing project developed solely by scientists (Kermish-Allen, Peterman, & Bevc 2019). Many co-created models focus on the educational merits of a project first, and scientific merits second. When working with a classroom in a co-created model, as stated by Kermish-Allen, Peterman and Bevc, "all participants are generators of content and knowledge as well as active learners" (p. 629).

Even when students develop questions alongside scientists, classrooms aimed to answer questions that have already been explored in scientific literature. Most student-guided projects do not lead to significant scientific findings, and could be solved in a similar fashion reaching for online resources (Scroggins, 2017). While students participating in co-created models can gain a deeper understanding of the scientific process as a whole compared to other participants in science-led models, little research has been done to study the educational merits of classroom citizen science (Price & Lee, 2013).

National projects

National citizen science efforts look at larger ecological projects such as understanding bird migration, measuring changes in long term climate, or working along

river or ocean systems. National projects benefit from having a variety of amateur experts in birding and astronomy (Clare et al., 2019; Scroggins 2017). These projects are mostly motivated by hobbyists dedicated to specific scientific topics, or by a national cause, such as saving the bees through planting and studying pollinator gardens. Citizen science is not limited to the borders of the United States, but the United States has a significant number of longer-lasting projects compared to other countries around the world (Pettibone, Vohland, & Ziegler 2017). National citizen science efforts are funded by the federal government, or receive national support through other organizations and nonprofits. Depending on the success of a project, something that initially started as a local effort can take on a national or global audience.

Cornell bird project & christmas bird migration

Citizen science is often treated as a new concept to active research, but in fact has been around longer than the term has been coined. The longest spanning project in the United States is the Christmas Bird Migration project that originated in 1900 and is ongoing as of 2020 (Scroggins, 2017). The Christmas Bird Migration project invites active birders to observe and record migration patterns on the same day each year. This project was used to build a sense of community among local environments by documenting birds passing by in an area, but held national significance in understanding bird migration as a whole (Scroggins, 2017). Birders would identify birds by calls, sightings, and share notes of their behaviors. The quantity visible of certain species would be documented and kept in a national record (Scroggins, 2017).

The Cornell Bird Project is a newer citizen science project developed from the phone application eBird. EBird gives people all across North America an opportunity to identify birds based on color, size and location. By identifying a bird through the phone application, data is documented by the bird species and location that can be used by scientists across the nation. Any of the individual bird sightings are kept away from public viewing in the case of endangered and vulnerable species to protect their existence. The collected data is distributed for ornithologists to use as necessary, allowing for multiple scientific discoveries to be made from the same set of growing data (eBird, n.d.). Volunteers for the Cornell Bird Project do not need to be experts or hobbyists in order to contribute to active research, and can passively be involved in citizen science research. The Cornell Bird Project also provides supportive educational content for classroom and educational facility use to tie into existing national standards (eBird, n.d.) Like many national projects, eBird and the Cornell Bird Project started new goals to reach a global audience and track bird migrations and population densities outside of North America.

Global projects

The current increase of citizen science projects started with the rise of Zooniverse, a website platform for scientists to upload data for citizens around the globe to look through and process (Zooniverse, n.d.). The projects vary from counting the number of penguins present, to classifying galaxies. Volunteers are trained and participating in less than five minutes at a time with easy access and simple tasks. The global platform through Zooniverse gives volunteers all over the world a chance to participate in

classrooms, homes, and more often than not, during nine to five work hours. Projects hosted on Zooniverse give participants a choice of projects to join in a long list spanning multiple disciplines, and require little dedication and time on the part of volunteers. Zooniverse is on trend with the current understanding and focus of citizen science projects where there is mass participation and low skill required to join (Price & Lee, 2013; Pocock et al., 2017). While participants on Zooniverse span nations across the globe, the greatest number of participants are within the United States (Zooniverse, n.d.).

Some of the participants actively make discoveries of never before seen phenomenons, but many participants take Zooniverse as an opportunity to pass time while benefiting active scientific research (Zooniverse, n.d.). Zooniverse, despite high rates of participation, fails to create educational incentive or value within their projects to participants and instead relies on the good will and interest of volunteers. The biggest incentive to participate in Zooniverse hosted projects is to do something in spare time between home and work.

Global projects struggle the most with creating a sense of community and collective knowledge among volunteers and scientists, but create greater quality data for surveying projects. The lack of community is remedied with online chat rooms where volunteers can directly communicate with scientists and other volunteers (Roy et al., 2016). Clare et al. (2019) found that volunteers that watched trail cameras to identify biodiversity in an area were able to identify common creatures (such as deer or cottontail rabbit) with over 90% accuracy, but unique creatures (such as a jackrabbit or fox) were misidentified at higher rates.

Citizen science over time

What citizen science looks like has changed from the original projects over 100 years ago, to the rise of citizen science in the late 1980s and early 1990s, to today (Pocock et al., 2017). Citizen science projects vary from continual monitoring with highly-trained volunteers, to simple training with one-time participation. Many citizen science projects fall in between the two extremes, but the identity of citizen science continues to change (Pocock et al., 2017). No matter how a citizen science is approached, there is a lack of studies on the educational merit of projects from highly trained or minimally trained volunteers. How volunteers participate in these projects vary from being involved hobbyists with yearly commitments to a project that requires high skill and training, to projects that anyone with a little time (no skill or knowledge needed) could participate in. Pocock et al. (2017) took a survey of over 500 citizen science projects found online to understand how volunteer participation has changed over time. Their discoveries between projects were split into a chart with four categories: systematic monitoring versus mass participation, and an elaborate versus simple approach.

A collection of online projects reveals a trend over the past thirty years towards a simpler approach with mass participation. The density of citizen science projects past 2010 also shows a steep increase in the number of available projects. Citizen science has become widely available and simplified for participants as recent as 2013, but there is no continuing research to explore what citizen science looks like in 2020 or projecting towards the future. Considering the continuing trend over time, citizen science projects were assumed to continue becoming simplified in task and requiring less experience to

participate (Pocock et al., 2017). If citizen science continues in this trend, the field will become increasingly accessible to citizens who do not know or participate in scientific volunteer opportunities.

Summary

Citizen science projects span across beaches and galaxies, from a few months to over 100 years. Citizen science projects are diverse in content and approach depending on the scope of a project. How people interact with citizen science projects and where it happens significantly affects the educational value to volunteers and scientific merit to researchers. Local projects are strongly connected to a sense of community, and personal responsibility working alongside classrooms or eager individuals. Many local projects have the potential for higher educational value for participants and felt a greater sense of collaboration with scientists.

National projects are dominated by astronomy and ecology related efforts. National projects generally take advantage of hobbyists or specialists and their content knowledge prior to participation to report findings and identifications. The biggest national projects focus on birding, with one project spanning over 100 years in the making (Scroggin, 2017). Global projects have the potential to reach out to previously unobtained audiences, but how to reach these people has yet to be explored considering the greatest number of participants are still within the United States. Global projects had the benefit of connecting people across the world, but rarely create a strong sense of community when compared to local or national projects. Global projects take place

online, predominantly through the website Zooniverse, a pioneer towards modern citizen science projects.

Citizen science projects continue to change in format over time; with many projects before 1990 requiring highly skilled volunteers in labor intensive tasks, to past 2010 with most projects requiring little training and one time participation (Pocock et al. 2017). The current trend for citizen science projects is to have mass participation with minimal skills required. The current trend for citizen science projects begs the question: Where does education fit in all this? How can scientists take advantage of citizen participation while creating continual purpose for participants? Developing a task for volunteers involves finding a balance between simple but engaging tasks where education can fill a role (Jones et al., 2018).

Active Research and Crowdsourcing Data

Citizen science thrives on community participation on large sets of qualitative data. The purpose for data collection and processing is not to produce busywork for researchers and volunteers alike, but instead centered around the very root of science: inquiry. Curiosity on the part of scientists and volunteers is a strong motivator to develop and participate in citizen science (Jones et al., 2018). Citizen science can take the place of computer-processed data, and in some cases provide an easier way to connect research with the public, and process data accurately. The human eye is better at catching unique details than a computer program is able to do, and with greater accuracy (Zooniverse, n.d.). Despite this, research misconduct is possible if volunteers are materially motivated (Rasmussen, 2019). A volunteer out for a paleontology fossil dig may not report found

fossils to keep for themselves, or a participant may consistently misreport data on dandelion heights because they were not trained properly in what units of measurements to use (Scroggins, 2017).

The process of using volunteers to help process data that would otherwise take one expert years or longer is considered crowdsourcing. Crowdsourcing data relies on eager participants motivated by science enthusiasm alone (Rasmussen, 2019). Crowdsourcing provides scientists with many advantages to process through data faster but fails to provide meaningful learning opportunities (Rasmussen, 2019).

Inquiry

Inquiry is at the basis of science and education, and the starting point for all citizen science projects and partnerships. In co-created projects, scientists collaborate with other professionals or volunteers to develop research questions (Price & Lee, 2013). Co-created projects are rarely demonstrated and did not provide the same amount of scientific merit as scientist led inquiry. Regardless if a project is co-created or not, inquiry is a motivating factor for scientists as well as participants (Price & Lee, 2013). Participants that are curious about the guiding research questions are more active, excited to participate, and retain a greater experience from science participation.

Crowdsourcing data

The rise of the current framework of citizen science spouts from a need to interpret higher quantities of data than professionals can muster. What would take years of image processing by hand for highly trained professionals, physically demanding repativitive scientific tasks, or impossible to muster tasks for data collection for field

locations can be better done with volunteer assistance (Jones et al., 2019; Rasmussen, 2019). Researchers are becoming increasingly reliant on volunteers to process large quantities of data. The greatest example to date is with the Andromeda project in Zooniverse, where over a year of data was processed by volunteers in less than a week (Zooniverse, n.d.). The Andromeda project looked at high definition photos taken over two thirds of the Andromeda galaxy and had volunteers identify star clusters, the remnants of other galaxies.

Crowdsourcing data eliminates analysis bias for many scientists but created new biases from lack of experience from volunteers (Clare et al., 2019). Volunteer bias is often not intentional unless externally motivated by predetermined expectations.

Research misconduct

Research misconduct happens in citizen science projects unintentionally, but there are ways to minimize outliers (Rasmussen, 2019). Research misconduct is primarily a result of poor communication between scientists and volunteers. By explaining what to look for during volunteer training, participants may become unknowingly biased to documenting larger flowers or picking up only certain types of fossils (and failing to recognize rare finds) during data collection (Scroggins, 2017). New discoveries may be lost entirely based on observational biases of volunteers, but this can be remedied by additional training, or accounted for as error or omission of data in the case of consistently misrepresented sources (Jones et al., 2019). Mass participation also helps keep data consistent and removes outliers through analysis.

Summary

Citizen science thrived from inquiry on the part of scientists to develop research questions, and volunteers to see the results and make their own discoveries. Scientists use citizen science as an opportunity to crowdsource data, but often fail to develop educational motivation for participation. As a result of poor training or bias, citizen science data can lead to unintentional research misconduct, leading to unusable data or analysis for any scientific literature use (Jones et al., 2019; Rasmussen 2019). Research misconduct was the biggest barrier that scientists have to face when considering developing a citizen science project. While research misconduct is a concern for proper review in science, concerns for participating scientists will be: how their research is viewed by colleagues, and how to maintain accurate data without complicating volunteer tasks.

Citizen Engagement & Developmental Process

Developing a citizen science project can be tedious for scientists without any previous educational experience. Scientists can take an opportunity to speak with the public about their research and understand how their community outside of academia may view their work through citizen science projects.Citizen science projects that find the most success have scientists consider what motivates participants, how to engage participants throughout their participation from data collection to analysis, consider the scope of their project and so on (Boney et al., 2009). Projects that struggle to gain participation failed to create a unifying motive altogether (Boney et al., 2009).

Ultimately, citizen science creates opportunity to educate a population for greater science literacy, and engage communities in active research.

Developing motivation & community engagement

Developing motivation for volunteers is difficult if the research question does not involve creating changes to their community, or accrediting citizens within the science paper by name or acknowledgments. Projects that fail to provide motivation to volunteers from the conception of the project fail to recruit and train participants. Before beginning a project, scientists need to develop a scientific question and a supportive team that includes scientists, evaluators and educators (Bonney et al., 2009). One of the most important pieces of the process that becomes neglected in unsuccessful citizen science projects is to develop, test and refine as well as create supportive educational material. Beyond developing motivations, scientists and staff on a citizen science project will also need to have open ears and hear of changes that need to be made in order to make a better volunteer and staff experience (Bonney et al., 2009). Open communication and listening between volunteers and scientists is key to a successful citizen science project.

Science literacy

Science engagement and science literacy has little correlation within citizen science projects that develop few to no educational resources prior to public engagement. Even when education is a focus of citizen science projects, participants are more likely to grow in content knowledge, but not the scientific process (Price & Lee, 2013). For hobbyists, their science literacy does not change at all through participation, and as a result reap little educational benefit from participating, but receive enjoyment from

benefiting science as a whole (Bonney et al., 2009). The correlation of science literacy with co-created projects has yet to be studied sufficiently. Ultimately, citizen science gives researchers an opportunity to create science literate citizens of all ages and demographics, but often fails to penetrate deeper than those with already invested interest in science. There are no mentions to the long term effects of citizen science of science interest, literacy or knowledge from those exposed to citizen science at an early age as a part of their school curriculum.

Summary

From the current understanding of the citizen science developmental process, education is a fundamental component for continual success on the part of scientists and participants (Bonney et al., 2009). Participants are motivated and invested in multiple endeavors when volunteering, and unless their motivations are met, a citizen science project may fail. Participants need to be engaged in the full scientific process to get the most educational merit out of a project. By understanding and developing motivations for volunteers and researchers, citizen science projects can reach a larger audience and find dedicated and invested volunteers.

Summary

Citizen science projects are on the rise within the last thirty years, and are on a trend to continue in frequency and variety. Citizen science gives scientists, educators and citizens an opportunity to participate in active research and gain a deeper understanding of science. Most citizen science projects neglect to incorporate education as a part of their base curriculum, and as a result fail to find participants and increase science literacy

within a community. These same projects also fail to expand the demographic of participants beyond those already invested in science. The stakeholders and their motivations vary with the scope of citizen science projects, but the two roles that receive the most focus are the scientist and volunteer. These roles are not the sole identities of individuals, with additional identities including educators, advocates and managers. The average volunteer is white, over fifty years old, well educated and male (Pocock et al., 2017). The lack of diversity in volunteers is a problem that faces the future of citizen science, but solutions have not been entertained yet.

Citizen science projects can take place in many different areas, from local, national and global reaches. Depending on where the project takes place greatly affects the sense of community among participants, and level of educational content developed. Local projects have a greater sense of community and educational success, but often lack the same scientific merit. Global projects have the capability of reaching volunteers across the world, but fail to change the common demographic of a typical volunteer and only engage those already invested in scientific inquiry. Global projects also fail to create a greater sense of community. Citizen science projects also span and change through time as well as location, with most citizen science projects leaning towards mass participation and simplified tasks (Pocock et al., 2017). The shift in citizen science creates fewer opportunities to engage the public in educational content, and instead has a greater focus on crowdsourcing data.

Crowdsourcing data is a way for scientists to sift through large data sets much faster than experts could. Many of these crowdsourced tasks are monogamous in nature,

and require little dedication or training for volunteers. By crowdsourcing data, scientists left their projects open to unintentional research misconduct if the volunteers were not properly trained or alternatively motivated.

Finally, developing citizen science projects need to consider the educational content from the conception instead of as an afterthought. Within the next part, a project was developed in the form of a presentation and online resources with content directed towards scientists interested in crowdsourcing data or community engagement on the importance of developing educational forward content.

Chapter Three explores the process of developing a capstone project that synthesizes resources for new and experienced researchers wanting to start citizen science projects. The resources will include a three part workshop where researchers openly discuss their concerns moving forward with a project, and experience the role volunteers take in citizen science. The goals of the workshop are to build community and understanding between researchers and volunteers, and to give researchers the resources necessary to successfully start their citizen science projects.

CHAPTER THREE

Capstone Project

Citizen science aims to engage the public in the scientific process by collaborating with professionals in well designed scientific inquiry. The majority of citizen science projects as of 2020 focus on mass participation in simple tasks for volunteers (Pocock et al., 2017). Through performing repetitive, simple tasks, volunteers do not receive the educational merit or knowledge of the scientific process or content knowledge from participating. Many scientists neglect the educational component to citizen science projects in favor of mass data collection and therefore fail to connect a desire for lifelong learning and passion for science. Some citizen science projects fail because of a lack in communication, and to develop solutions that create a better narrative for researchers and volunteers (Price & Lee, 2013). This capstone project is designed to work alongside active or starting researchers to develop resources and support for a balanced citizen science project. The project aims to bridge the gap between researchers and volunteers through activities and discussion. By providing support for citizen science projects from the beginning, there will be greater opportunities for incorporating education and communication. *What makes a citizen science project successful? How can a better understanding of the relationship and expectation between researchers and volunteers create greater success?*

The capstone project is a three-part workshop offered to researchers on how to begin their citizen science projects, seek out fitting volunteers that best support their project needs and develop lifelong relationships with other researchers. This project

focuses on educating researchers to minimize common project failures in citizen science, develop stronger relationships with participants, and teach researchers how to effectively engage citizens in their research for a welcoming and educational experience for all. The project will also help researchers visualize volunteers as colleagues. This workshop was developed over the spring of 2020, looking towards the popular ecological citizen science season over the summer, and offered in April for Citizen Science Month. The original workshop was developed for the DIYBio organization (Do-It-Yourself Biology). DIYBio focuses on connecting the public with biotechnology and ecology through collaborative projects with actively interested citizens. Reaching citizens for these projects can be a daunting task for new scientists, and often unsuccessful. Considering the vast interest in citizen science opportunities within the group for collaboration on projects with citizens, DIYBio is a great focus group to get feedback and educate on the importance of developing strong relationships with the public.

Project Description

The project is a three-day workshop designed for researchers already involved in citizen science projects or plan on starting one. The project focused on making a local impact and met with researchers locally since local citizen science is where researchers can make the greatest impact on the public. The project aims to empower and motivate scientists to deeply engage their volunteer base in the scientific process and content knowledge, and to treat volunteers as peers. Many interested and capable volunteers already have a basis for content knowledge within the field of study, but rarely engage in the scientific process themselves. Citizen engagement is strongest with data collection

and analysis but often neglected in education and follow up. Based on the scope of various citizen science projects, the workshop material is developed to be generic enough to fit a formula for any local projects but can connect to a wider global community in ecology, paleontology, astronomy, and other scientific disciplines. Since citizen science projects vary in content knowledge and volunteer involvement, the workshop focuses primarily on local projects that benefit the most from strong educational development and scientist-volunteer relations. Building a stronger scientist-volunteer relationship is done through a variety of activities and discussions to understand motivation, identity and capability.

The project is predominantly a series of activities and discussions directed towards researchers on how to connect their projects to educational and research goals, understand how their project relates to a community, seek out volunteers that will gain the most from participating in their projects and developing a lifelong love of learning for all participants. The project offers supportive educational content for researchers as a guide for developing citizen science projects through open discussions where every participant will be able to share their experiences and concerns. The workshop allows researchers to find content that best fit their project needs, and how to pursue volunteers that fit their project goals and create lasting relationships with colleagues pursuing similar projects.

Rationale

The goal of this project is to bridge the gap of communication and skills between researchers and volunteers. Since volunteers and researchers can take on many different

identities, researchers need to be cognizant of their participants and how to best incorporate their skills as hobbyists, activists, and students into greater science literacy within a community (Price & Lee, 2013). The approach to addressing the disconnect in communication with scientists and volunteers iss to develop supportive content for scientists that encourage them to make meaningful interactions and develop their own appropriate supportive content alongside their project. Education is an important component of citizen engagement in these types of research projects but was often left as a secondary concern to the original research question (Bonney et al., 2009). Many researchers are not trained to be educators, but with assistance create more meaningful relationships with volunteers that fostered a lifelong investment in learning. By developing educational content concurrently for volunteers, researchers have an easier time engaging others and developing stronger relationships with their volunteer base. Developing strong relationships with the volunteer base help researchers spread interest in their findings, created a deeper connection with science, and fostered a lifelong investment in learning for all ages and abilities. The workshop also aims to decrease the hierarchical relationship between researchers and volunteers by interviewing volunteers, and giving researchers opportunities to be volunteers themselves.

Audience & Setting

The project content is not designed for educators, but researchers within universities, science committees, and hobbyists pursuing crowdsourcing data to fulfill research goals. The ideal audience will be new to leading citizen science projects, but already familiar with the basic concepts or with previous experience participating. This

workshop accommodates a group no larger than 20, and has many opportunities for interaction through discussion, activities and self-reflection. There are many national organizations and universities that use citizen science as a way of crowdsourcing large quantities of data from self-motivated volunteers. By giving researchers the tools needed to develop motivation for education, researchers will be able to keep an active and passionate volunteer base. Since many of the participants will already have backgrounds in science, the workshop will provide opportunities for everyone to share their experiences and how it relates to citizen science (Knowles, 1992).

DIYBio (Do It Yourself Biology) is a nationally recognized organization with local chapters across the United States. The mission for DIYBio is to empower do-it-yourself biologists with public lab spaces, and engage the public in biotechnology projects. Some local chapters further focus on connecting people interested in biology with scientists to develop projects that engage the public in biotechnology discussions. This group of highly trained scientific minds is the ideal audience for me since they are already motivated to work alongside the public, and want to be more effective science communicators.

The project is intended to be held as an open workshop for all researchers developing, or already a part of, a citizen science project. The workshop took place over three sessions, each building on the previously explored concepts. The workshop focuses on local projects and researchers since the biggest impact to community science literacy is by directly connecting with volunteers in live events. The supportive handouts give researchers the tools necessary to connect with volunteers and share their research

openly. The workshop includes a space for researchers to communicate with one another about their successes and struggles.

Project Outline & Timeline

The workshop approaches researchers with guiding questions to understand what types of volunteers would best engage with their own work, and how to share their research without using exclusive language. The first step was to develop a comprehensive list of resources for researchers into understanding the value of incorporating education into their own research process and understanding their volunteer base to support a sense of curiosity and worth. The workshop is designed to work with a small group of researchers with existing or planned citizen science projects to maximize participation potential (Knowles, 1992). Parts of the discussion help researchers determine their ideal volunteer, how to recruit new people, and maintain existing relationships through a plethora of relatable educational content and social media.

The workshop was put together before the summer volunteer season, and intended for presenting mid-April. The workshop offers activities and discussions that look at scientific inquiry, motivations, task design, volunteer identities, and measuring success. The workshop doubles as an opportunity for researchers to share their own successes and struggles, and take the role of volunteers themselves.

Limitations

Citizen science projects offer important specific details that were unique to the scope of a project. The project to connect scientists with citizens is not able to address all of the specific needs for national or global research, but best reflect the capabilities of

local projects. Each individual project is also diverse in scientific content and expectations, and this workshop is only able to address general, common concerns. By preparing scientists to work with citizens, and understand their motivations, scientists can be prepared to inspire, motivate and mobilize a population. Additionally, if a researcher is isolated by their project design or doesn't fit in socially with the rest of the intended audience, the researcher will have difficulties forming supportive relationships beyond the scope of the workshop. While not every scientist will have tools developed specifically for their project, they will leave with general tools for most citizen science projects. With this in mind, the success of the citizen project is still on the scientist and their team, and data collection can still be successful without fully engaging citizens on a deeper educational level. Crowdsourcing is not the same as citizen science, but still fulfills researcher needs in most cases.

Summary

The capstone project consists of a workshop for researchers interested in developing or improving their citizen science projects locally. Engaging the community is an important part of community research, but the educational component is treated as an afterthought in most citizen science projects. As a result, researchers lack the skills to maintain a consistent and motivated volunteer base. The workshop provides researchers with a space to ask questions, identify the needs of their projects, develop a volunteer identity for their project, connect with other researchers, connect with volunteers, and find growing success with their projects by creating open dialogues. For successful communication between scientists and volunteers, education needs to be incorporated in

every step of the project. With successful incorporation, researchers and educators can help create a more science-literate citizen, and create a deeper engagement in science for years to come. Communication starts with the scientists, and this project addresses the importance to teach scientists the value of education within the projects, and understand their volunteer base to support both their needs with data collection, and education.

Chapter Four explores the lessons learned through the development of the project and analyzes successes or changes that would be made in future renditions. Chapter Four also explores how literature informed the capstone project and future research.

CHAPTER FOUR

Conclusion

Citizen science is a growing and changing field of research that combines educational and scientific values to engage the public. Original citizen science projects heavily engage volunteers in specialized tasks, while the current trend for citizen science projects includes simplified tasks for a broader audience (Pocock et al., 2017). As the future of citizen science continues to change, the volunteer base remains predominantly white, male, over 50 and highly educated (Jones et al., 2018). Citizen science has the potential to reach a more diverse audience if researchers are made aware of the problems, and are given a space to share their concerns without judgment or fear of failure. Many citizen science projects fail to launch or lose traction within the first year because of common pitfalls and struggles that are not well documented or shared between researchers. Even projects that continue beyond the first year struggle through the same pitfalls by not listening to volunteers, or learning to be okay with how their research is interpreted by the public (Scroggins, 2017). This led to the research question: *What makes a citizen science project successful? How can a better understanding of the relationship and expectation between researchers and volunteers create greater success?*

A workshop developed to explore this research question in a way to prepare new researchers for success at the start of their citizen science project. The workshop prepares researchers to fully engage volunteers and gain a better understanding of the educational and social component to their research project through open conversations and practice

with volunteers. This workshop took place over three sessions and engages scientists through experiencing the role of volunteers.

Chapter Four discusses the major learning from developing the project, revisits the literature review in chapter two to see which sources and thinking influenced the project the most, look at the broader implications on citizen science from the workshop and limitations that were found throughout the project development. Finally, Chapter Four will look ahead at future research possibilities to expand on the concepts already presented in the project, and next steps in research to build off of known concepts.

Major Learnings

The workshop is designed to give researchers a chance to fully develop their research questions, learn about what their ideal volunteer base is for their project needs, understand their own underlying motivations alongside volunteers, develop healthy ideas of success that go beyond data collection, and create a lasting support network with one another. Throughout the development of the workshop, discussions are considered essential for participants to share their experiences. Later on, activities are included to help guide discussions and to provide progressive breaks from continuous discussion. While this workshop was originally designed for both new and old researchers to citizen science, in the end, it better suits the needs for researchers that are newly developing or interested in citizen science. The workshop provides a safe space for researchers to experiment with social aspects of their projects, and develop equity with volunteers through shared experiences. Because of my personal experience as a scientist, volunteer and educator, I developed the workshop in a way that would bring those identities

together, and give researchers opportunities to be in the role of an educator and volunteer. While thinking like an educator is never explicitly mentioned within the workshop, the idea is threaded throughout the experience.

The workshop can be a powerful tool for citizen science projects and set forth a plan to skip over the common pitfalls in beginning a research project based on crowdsourcing data. I picked out activities that addressed the major issues I've witnessed from my own personal experiences to create a better relationship and healthy expectations within a project. I thought of where my own experiences felt lacking as a volunteer, or researcher, and aimed to prevent them as a mentor I did not have when starting a new citizen science project. Having guidance at the beginning of a project prevents researchers from falling into the same pitfalls that predecessors had. If I had guidance when developing a citizen science project, I would be prepared to handle the challenges of managing and engaging volunteers as a researcher, or developing a fun experience for a specific audience and incorporating educational content to the experience from the beginning of the development. As a researcher, I never had a target volunteer group to reach out or the means to approach others. The real goals of the workshop became more obvious as it came to life: a way to bridge thinking between researchers and volunteers on a foundation of respect. This is accomplished by looking over volunteer identities, placing researchers in the role of volunteers through activities, and openly discussing and reflecting on failure and concerns. Additionally, when asking for public support on a project, it is important for volunteers to understand where the research is going. I never knew what I should and shouldn't share with the public when

leading citizen science projects, but now I know that it is important to share all of your data and project design. There is power that comes with building a community through foundational science.

By developing a foundational relationship between researchers and volunteers, citizen science projects will be able to focus on more than just data collection and processing, but also education, community and science literacy. Ultimately, I also chose that the best way for researchers to stay connected is by exchanging contact information with one another at the end of the workshop instead of developing a community site or or online group since not every researcher has personal social media. This way, researchers are able to keep more personal connections where the responsibility to maintain the connections made relies of their own merit.

Revisit Literature Review

Scroggins' (2017) article, "Ignoring Ignorance: A Note on Pedagogical Relationships in Citizen Science," greatly influenced the final workshop since Scroggins shared his own experiences developing a citizen science project and the struggles through that process by ignoring volunteer concerns and desire for participation. This article was a great way to open researchers up to sharing their own experiences with citizen science, and a platform to avoid common pitfalls when starting a project. Scroggins' article gave researchers an opportunity to open up about their own experiences and struggles through a welcoming example story.

Toft et al. (2017) and Pocock et al. (2017) provided articles that informed my choice of framework by looking at historical models and current trends for citizen science

roles. Their articles played a big role in understanding volunteer motivations and current understandings of citizen science frameworks. Pocock et al. explored how citizen science projects have changed over time leading to less complex tasks for a wider audience. Understanding the current trends in the citizen science framework can help researchers develop tasks that fit their research and education goals.

Jones et al. (2018) provided a deeper understanding of citizen motivations for participation in different projects. Jones et al. provided a comprehensive way to understand what motivates volunteers to participate and the common identities found. Understanding volunteerism and what motivates people to participate, and other to not, was integral to finding volunteers that fit a project for researchers. Understanding volunteer motivations and who is missing from that picture can also help inform researchers on how to seek diverse groups through classrooms and rewarding experiences.

Broader Implications

The workshop will provide broader implications on the changing form of citizen science, and perhaps push researchers towards more involved volunteer projects instead of the current trend of simplified tasks and little specialization (Pocock et al., 2017). Ideally, the workshop will also open researchers up to recruiting volunteers from diverse backgrounds instead of just those already engaged and motivated by science. By understanding volunteer motivations and picturing themselves as volunteers, researchers will be more prepared to lead citizen science projects. Those who attend the workshop will have the tools and confidence to lead a new citizen science project, and continue to

share their trials and tribulations to create a deeper understanding of citizen science as a whole. Citizen science is a changing field, and these changes can be documented by shared experiences between volunteers and researchers.

Limitations

The year this workshop was developed was in the middle of the COVID-19 outbreak across the globe. This external incident heavily affected the availability to collaborate with coworkers, DIYBio and the content reviewer. The COVID-19 outbreak also came at a time where I would have reconsidered the format of the project so it could be held online, or self-guided instead of given in person.

Since many citizen science projects also rely on funding, this piece has been assumed as part of the workshop as a later topic to pursue or one that has already been covered by their organization. The workshop also assumed that researchers are already motivated to incorporate community in their research, but lack the knowledge of how to include volunteers in a meaningful way. The workshop is best suited for those who are new to citizen science instead of those with already existing experience.

Bringing in volunteers to share their experiences in citizen science projects will also be a challenge for the facilitator unless there are existing connections. Even more so, volunteers should be prepared for the possible questions from researchers and ‘lifting of the veil’ to see how citizen science projects are developed and designed. Not every volunteer who has participated in citizen science will want to speak about it with researchers, and diversity will be difficult to represent. The chosen volunteers will need

to be dedicated to openly sharing their experience and bettering future citizen science projects as a whole.

While I initially envisioned the workshop to be free, I think a minimal fee of $5-10 would be better to consider food for the third part of the workshop. The cost of the facilitator and materials was not taken into consideration either in the original workshop and would need to be reevaluated.

Discussion of Future Research

The project can continuously be improved by making the resources available online and creating a way for the workshop to be delivered online. By making the workshop available online, a greater number of researchers across the globe will be able to participate. Citizen science is a global touchstone to crowdsourcing data, and a waypoint to create a science literate public. By reaching a global audience through online means, the same workshop will be able to create a greater impact on how citizen science is implemented as a whole, and be able to accommodate projects that are not reliant on personal communication or local factors.

Additionally, the workshop could be reworked to fit an already determined research group around one project. In this design, there will be greater focus on a singular project, and the facilitator can act as a mediator to fixing an already existing project. With this design, the activities will focus more closely on developing a strong team of researchers, educators and volunteers.

With this, parts of the project will need to be simplified and further generalized to create a cohesive and form fitting lesson for a larger variety of citizen science. An online

workshop will also create opportunities to build community on a global scale and create a formula for success through researchers sharing their experiences with both failure and triumphs.

Aside from a continuing workshop, future research can also focus on getting a greater understanding of volunteer and researcher relationships through interviewing researchers with active or finished projects, creating open discussions with volunteers to gain a better sense of what volunteers are seeking out for their citizen science experience, and diving deeper into problematic aspects of volunteerism and how volunteers that participate in citizen science projects do not reflect the national or global population as a whole. The lack of diversity in volunteerism as a whole is a growing problem, and citizen science, with the ability to act in public schools and spaces, can be a part of the future to creating a diverse volunteer base.

Communicating Results and Benefits

The workshop addresses the imbalance in relationship between volunteers and researchers. Having a strong understanding of researcher and volunteer motivations, and having a clear idea of a project lead to greater success within citizen science. The workshop will be successful if the researchers leave with a greater sense of community with their fellow researchers and volunteers. Evaluation forms will be given out to gain a better understanding of how the workshop can evolve as researcher needs change. The direct benefits to researchers will be a better grasp of who fits their citizen science project, where to make those connections, and having healthy expectations for the first year. Researchers will also create connections with one another, and potentially

collaborate on citizen science projects. The longer benefits will come from researchers sharing the workshop with their colleagues, and hosting the same workshop each year before the summer volunteering season.

Final Remarks

Citizen science is a new field of research that is still finding a footing in 2020. Even though citizen science has been around for over 100 years, the growth citizen science has experienced over the last 50 years has been exponential especially with the rise of the internet. Citizen science has been changing into a field that allows people from all backgrounds and ages to participate, but lacks the diversity that could be. Developing a relationship between volunteers and researchers can help bridge the gap in diversity, create a science literate public, and create strong communities on a foundation of science. The workshop developed aims to create a deeper understanding for researcher and volunteer motivations, prepare researchers to start their project with healthy goals and connect communities. By creating an equal relationship between researchers and volunteers, a citizen science project will be able to find success and create a worthwhile experience for all parties involved. The workshop can also expand in an online space for a global audience, and even more personal with already existing citizen science groups that need assistance to find success.

Research remains insufficient in understanding diversity in volunteerism, relations in citizen science projects and a framework for developing a project. For a citizen science project to be successful, volunteers, researchers and educators need to understand one another and collaborate. Through collaboration, researchers and educators

can develop a working framework for citizen science projects across the globe, and continue evolving citizen science into a field that is diverse, engaging and educational in addition to its scientific merits.

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