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Confluence: Evaluating the Individual Learning Outcomes of a Combined Citizen Science and Environmental Education Project

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Abstract

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Citizen Science has moved beyond a methodological tool for ecologists to crowdsource data to a novel platform for environmental and informal science education. However, few studies document the individual learning outcomes of citizen science as an educational tool, particularly in youth or extension education. This quantitative study focused on evaluating the individual learning outcomes of an environmental education and citizen science non-formal learning experience about water quality.

In this study, an existing lesson plan using four sequenced activities was adapted for use with West Virginia 4-H summer camps in 2022. Potential outcome areas were first identified from foundational environmental education theory and emerging citizen science frameworks. Learning outcomes were evaluated by comparing pre-participation and post-participation survey responses with paired t-tests, McNemar tests, and descriptive frequencies during four, week-long summer camps at Jackson's Mill 4-H camp.

The results showed an overall success of the activities, based on statistically significant positive increases in Interest in science and the environment, Knowledge of water quality and citizen science, and Stewardship intentions. By understanding these outcomes, we can better plan citizen science learning experiences to best meet targeted outcomes and act as an effective platform for education

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Chapter 1: Introduction

The past three decades have seen a considerable growth in social science research focused on citizen science (CS), interchangeably referred to as public participation in scientific research, citizen and community science, or volunteer monitoring (Bonney et al., 2009b). As a tool for research, citizen science provides efficient data collection– especially at large geographic and temporal scales (McKinley et al., 2017; Sullivan et al., 2014). When following training and data best practices, citizen science data are high quality and suitable for use in published research (Fuccillo et al., 2015; van der Velde et al., 2016). More recently, citizen science researchers have investigated the benefits, outcomes, and impacts of participation on the participants, in addition to technical aspects of data quality (Dickinson et al., 2012). Information on these outcomes has important implications for program design.

Citizen science programs and projects have started using conceptual models incorporating educational goals and objectives. These programs recognize the potential value of citizen science as an educational tool for greater understanding of science content and the research process (Bonney et al., 2009a, 2016; Phillips et al., 2018). Under the broad umbrella of informal science education, major learning outcome categories have been identified (Friedman et al., 2008; National Research Council, 2012; Phillips et al., 2018). These major learning outcome categories developed by Phillips et al. in 2018 are broken down into Interest; Self-Efficacy; Motivation; Content, Process, and Nature of Science Knowledge; Skills of Science Inquiry; and Behavior & Stewardship. These outcomes were derived from research focusing mainly on adult citizen scientists, suggesting room for increased research on youth. Further, most of the biodiversity focused CS projects reviewed by Peter et al. (2019) focused almost exclusively on assessing content knowledge outcomes. While content knowledge is foundational to understanding citizen science, the other categories still need to be better understood. Peter et al.'s 2019 review also shows that participant outcomes are seldom researched in biodiversity citizen science projects. Of 608 articles, the authors found only 14 containing research or evaluation on any learning outcomes for participants.

Despite the growth of citizen science as an educational format, there remains little research on youth learning outcomes (Dickinson et al., 2012). Citizen science complements existing formal science learning by providing an inquiry-based, hands-on approach to environmental science (or any other type of science) that educators are increasingly seeking out for their students, as some already do with environmental education. Environmental education (EE) seeks to educate towards action for the environment through a number of methods and settings (Ardoin et al., 2020; Hungerford & Volk, 1990). Combining the dual hands-on approaches of EE and CS could achieve not only individual learning outcomes, but important social-ecological outcomes to improve environmental health and the systems humans use to improve it (Wals et al., 2014).

The purpose of this study is to identify the changes in learning outcomes in youth 4-H summer campers during a combined citizen science and environmental education experience. While much of the existing research on citizen science outcomes is primarily quantitative, each program and setting may vary. This study used standardized, commonly used survey items and scales to assess the changes in youth, adding to the body of knowledge related to citizen science outcomes. The combination of the citizen science outcomes framework developed by Phillips et al. (2018) and an environmental education program and outcome framework from Hungerford & Volk (1990) were used to identify appropriate learning constructs to assess in a collaborative citizen science project. The Phillips et al. (2018) framework primarily guided our research questions, which focused on the identified outcome areas of Interest, Knowledge, and Stewardship. The Hungerford & Volk (1990) framework helped define the creation of our treatment (lessons). Framework utilization and hybridization will be addressed further in the literature review. Overall, we wanted to see how these outcome areas worked with 4-H youth campers to deliver sequenced EE and CS activities, all related to a creek water quality monitoring CS project.

The specific research questions are:

1. How does participation in a collaborative citizen science program impact youth's **Interest in science and the environment**?

2. How does participation in a collaborative citizen science program impact youth's **Knowledge of conducting science, water quality, and citizen science**?

3. How does participation in a collaborative, citizen science program impact youth's **beliefs and/or actions about Stewardship**?

Chapter 2: Literature Review

Citizen Science

Citizen science is the involvement of non-experts in scientific research (Bonney et al., 2009a, 2009b, 2016; Dickinson et al., 2012). Participants usually contribute to or collaborate with professional scientists at varying levels to answer questions and provide data for projects that would be difficult to do individually (Bonney et al., 2009b). Because the professionalization of science is a relatively new phenomenon in human history, the first “citizen scientists” may have been early humans monitoring seasonal and climatic change as it affected foraging and early agriculture (Tengö et al., 2021). Many scientists and inventors in the 18th and 19th centuries could also be considered citizen scientists as they lacked formal institutional training (Miller-Rushing et al., 2012). However, citizen science as we understand it today has only been a distinct field since the 1990s (Bonney, 2021; Bonney et al., 2015). Research on citizen science reflects this, and the participant learning outcomes of the burgeoning citizen science projects have only recently been purposely planned for (Bonney et al., 2009b).

Even though CS is a relatively recent field, researchers have begun reviewing the state of knowledge of citizen science. They have also looked at trends as evidenced in a diversity of studies, outlook papers, and conference plans (Bonney, 2021; Bonney et al., 2009a, 2009b, 2014, 2016; Jordan et al., 2012; McKinley et al., 2017), and these trends are briefly detailed below. Participation in citizen science has dramatically increased due to mobile applications and other portable and online tools that increase accessibility, like iNaturalist and eBird (Bonney, 2021). Because of this increase in accessibility of data contribution opportunities, there are concerns about data quality in the academic community (Lukyanenko et al., 2016). Despite this mass, non-expert data acquisition, data generated by citizen scientists is frequently used in published scientific research (Bonney, 2021; Follett and Strezov, 2015; Fraisl et al., 2022). There are best practices for making sure citizen science data is accurate, from training to quality assurance measures (Bonney, 2014; Kosmala et al., 2016; Wiggins et al., 2011). Though research exists on these technical aspects of citizen science, we have a limited understanding of the effects of participation on citizen scientists themselves. Further research is needed in the area of citizen science participant outcomes to inform programming and best practices. Then, we can achieve desired individual, ecological, and community-level outcomes (McKinley et al., 2017; Phillips et al., 2012).

Citizen Science Frameworks

A number of frameworks have been developed and applied to categorize the types of citizen science projects, but a handful have become common reference points and can be used as evaluation tools (Phillips, 2018; Shirk et al., 2012) . One frequently referenced framework strives to characterize the citizen science project by the level of participant involvement, moving from a Contributory model where participants simply contribute data to a research project created by a professional (volunteer monitoring), to a Collaborative style in which participants collaborate on the research design; to finally the Co-created model, in which citizen scientists have the largest role in co-creating the entire research project, from developing the research question in the beginning to communicating the results at the end (Bonney et al., 2009a; Shirk et al., 2012). This framework is detailed in Table 1 below.

Table 1: Models for Public Participation in Scientific Research (from Bonney et al., 2009a)

Step in Scientific Process	Steps included in Contributory Projects	Steps included in Collaborative Projects	Steps included in Co-created Projects
Choose or define question(s) for study			X
Gather information and resources			X
Develop explanations (hypotheses)			X
Design data collection methodologies		(X)	X
Collect samples and/or record data	X	X	X
Analyze samples		X	X
Analyze data	(X)	X	X
Interpret data and draw conclusions		(X)	X
Disseminate conclusions/ translate results into action	(X)	(X)	X
Discuss results and ask new questions			X

X = public included in step; (X) = public sometimes included in step

A separate citizen science framework focuses more on a system for planning and evaluating specific outcomes of participation in citizen science (Phillips et al., 2018). This model is ultimately rooted in Informal Science Education (ISE) guidelines (Friedman et al., 2008; National Research Council, 2009). ISE is relevant to citizen science because many projects take place in informal science learning environments: parks, nature centers, museums, community centers, and online. Phillips bases her outcome categories on the “strands” (National Research Council, 2009, p. 251) and “impact categories” (Friedman et al., 2008, p. 11) developed in these ISE guidelines.

The six outcomes that she arrived at are: 1) interest in science and the environment, 2) self-efficacy, 3) motivation, 4) knowledge of the nature of science, 5) skills of science inquiry, and 6) behavior and stewardship. In the planning and development stages, citizen science projects can plan to achieve several of these outcomes at once, but one project should never try to accomplish all of them. This framework has been used by others to evaluate their CS project outcomes (Peter et al., 2019; Phillips, 2021).

Other frameworks for understanding and planning citizen science projects primarily use logic models, a common format for understanding a variety of inputs and outputs. Though these are not exclusive to citizen science, they are frequently used in planning and evaluation (Shirk et al., 2012). Beyond these, the literature contains several paper-specific frameworks for looking at citizen science. Ballard et al. (2017b) grouped outcomes into five categories that were different from Phillips et al. (2018), to analyze participation in citizen science in natural history museum settings. These educational outcome categories were framed around their contribution to conservation, and included: BioBlitz Events, Ongoing Monitoring, Bounded Research, Policy Outcomes, and Livelihood outcomes. In each of these categories, she discusses mainly changes in knowledge that led to these outcomes, as well as self-efficacy, both of which fall under Phillips et al. 2018 model. Another differing framework, Dispositional-Organizational Interaction Framework, used by Lopez et al. in 2021 evaluated the backgrounds and motivations of individual citizen scientists, coupled with the characteristics of the host organization to explore the overall satisfaction of citizen scientist volunteers. This "Dispositional-Organizational Interaction Framework" is a lens for understanding how organizations meet the needs and motivations of participants. An important motivation for CS participation analyzed in this project is knowledge attainment, reflecting the desire of volunteers in citizen science to learn something new (Lopez et al., 2021). Knowledge is a fundamental construct area of Phillips et al. 2018 framework.

Citizen Science in Relevant Contexts

In the United States, the Cooperative Extension Service is an organization that takes different forms in different states but continues to be a relevant educational outreach tool for agriculture and forestry in rural communities from land-grant universities (Herren & Hillison, 1996). 4-H (Head, Heart, Hands, Health) is a youth program of many extension services, designed to provide learning opportunities to help develop skills and attitudes to become more active citizens. Traditionally, agricultural skills were the main focus of 4-H, but the programming has expanded into many areas, embracing STEM/STEAM principles (Borden et al., 2014). Despite the hands-on nature of Extension Education and 4-H programming, published research on citizen science is limited in these settings (Clyde et al., 2018; Meyer et al., 2014; Posthumus et al., 2013; Snyder, 2017). The papers that do exist are generally theoretical or conceptual papers, expressing various sentiments and ideas about how citizen science ought to be applied in extension education settings and other rationale for why the two are a natural fit. Clyde et al. (2018) lay out a manifesto for Extension staff to implement citizen science using existing programs including 4-H, Master Gardener, and Master Naturalist programs. All these papers conclude that extension education is ripe for citizen science inclusion, but research is still clearly needed on how it is actually implemented in these settings, and how well extension educators are accomplishing desired outcomes. Unpublished program evaluations may be more common in these contexts and settings, but the published literature agrees that there is room to grow in using citizen science as a tool for positive social-ecological outcomes.

Citizen science is commonly used and researched in water quality investigations and monitoring. One of the most notable projects in this space is Dickinson College's Alliance for Aquatic Resource Monitoring (ALLARM) volunteer monitoring network, but many watershed organizations, parks, and other groups frequently use citizen science in this realm. ALLARM's monitoring is the focal point of Wilderman and Monismith's 2016 study, in which they focus on the technical aspects of the program, mainly addressing rural stream monitoring in areas threatened by hydraulic fracturing (fracking) for natural gas. While this study identified several ideas about the effectiveness of the data that this program collected, it didn't explicitly touch on the outcomes that participants received. There are a handful of researchers looking at citizen scientist outcomes in water quality settings, however, addressing diverse outcomes in areas such as social networks (Overderest et al., 2004) and general learning outcomes relating to interest and awareness (Brouwer et al., 2018; Lopez, 2021; Cooper et al., 2017). Cooper et al. (2017) went further, comparing motivations, barriers, and outcomes between consumers and producers of citizen science data, attempting to address several large outcome categories at once. Despite water quality being a common field to practice citizen science in, the body of research is relatively small in regard to participant outcomes, especially youth outcomes.

Environmental Education

Environmental Education (EE) is education not simply about, but for, the environment. It encompasses a vast diversity of topics, settings, and participants (Stern et al., 2014). In the United States, historians trace the beginning of the field primarily to the environmental movement of the 1970s which created momentum towards policy and social change for environmental education. This took form in the short-lived Environmental Education Act of 1970 as well as the early formation of the professional organization known today as the North American Association for Environmental Education in 1971 (NAAEE). In 1977, the Tbilisi UNESCO-UNEP Intergovernmental Conference on Environmental Education formalized the field on an international level (Carter & Simmons, 2010). A more academic and formal approach to environmental education research slightly predated these actions with the first issue of *The Journal of Environmental Education* in 1969 (Gough, 2016).

Environmental Education as a whole is more than content knowledge about the environment. Spanning a range of settings, topics, audiences, and outcomes, EE has the ability to change learner behavior towards responsible environmental citizenship (Hungerford & Volk, 1990). From social psychology, the idea of cognitive hierarchy tells us that attitudes precede and direct behavior change (Vaske & Manfredo, 2012). Targeting attitudes to address behavior change is a central concept of EE. In formal education settings, EE often takes the form of curricular experiences that might be one class, or a whole school year. These formal experiences are often carefully designed to achieve certain educational outcomes. For primary school students, they may be targeting environmental awareness outcomes, while high school and college student educational experiences may aim for deeper knowledge, skills, and stewardship. While the outcomes can be similar, nonformal EE is often a one-off, more interpretive experience (Biedenwig et al., 2015). While EE can be honed to any target audience one wants, the primary audience of environmental education is usually youth. Youth EE can be viewed as an investment strategy - they may not change behaviors immediately or be able to take or demand action, but exposure to EE over time can result in more environmentally responsible adults, who may not need immediate, action-oriented programming to change behaviors if they have developed an ecological mindset (Peace Corps, 1995). On a practical level, youth are already in formal education for a large part of their lives, so it is logistically easy to expose them to EE as a captive audience in a school. By contrast, adults have to be advertised to, and have a self-selection issue with people already interested in environmental issues being the ones continuing to return to environmental education experiences (Haugen, 2010).

An important factor in the success and prevalence of environmental education is the ability to fit into state educational standards. The most up-to-date guidance takes the form of Next Generation Science Standards (NGSS) developed in 2012 (National Research Council, 2012). Broadly, the NGSS is structured around switching science education standards from a focus on memorization of specific facts to allowing for student inquiry and investigation, making environmental education practices suitable for achieving these science standards. Some criticisms around earlier standards, particularly 1996's Science Education Standards (NSES), state that standards reduce the ability for effective environmental education by forcing educators to focus only on certain concepts and direct instruction rather than inquiry (Bentley, 2010). Brown (2001) found that these same standards actually do contain similarities to EE best practices but require teachers to get creative about linking standards to best practices. Brown went on to identify shared processes and content areas between NSES and EE, including an overall adherence to Hungerford & Volk's 1990 continuum of awareness, understanding, and action. He does note, however, that explicit mention of concepts like sense of place and other big ideas in EE are conspicuously absent in the 1996's NSES standards, and only implied in the current NGSS. Today, while the standards have begun to shift towards more experiential learning processes and settings, allowing EE to be a suitable tool in the classroom, but also to lead students out of the classroom to engage with the environment.

Stern et al.'s 2014 systematic review of the outcomes of participation in environmental education tells an important story. This meta-analysis of empirical research regarding youth learning outcomes in EE from 1991 to 2010 compared current best practice guidance from NAAEE to research findings, and the authors found overwhelming support for the existing best practices and the outcome areas of knowledge, awareness, skills, attentions, intentions, and behaviors. Scientific assessment is mostly circumstantial, as the research is generally unique to an individual project or curriculum, but identifies a plethora of benefits that participation in environmental education can result in. These strongly overlap with the lived experience of practitioner, consensus-sourced outcomes, mainly evidenced in NAAEE's 2012 *Guidelines for Excellence*. These guidelines resulted from a participatory process of interviewing practitioners and researchers alike to understand common best practices and outcomes. Overall, the authors emphasize the need to empirically isolate outcomes in EE research.

Environmental Education Frameworks

One of the most common frameworks for environmental education is the Environmental Citizenship Model (Hungerford & Volk, 1990). This model (Figure 1) proposes that individuals can potentially move along a stewardship spectrum if they are strategically exposed to new information, ideas, and activities over time.

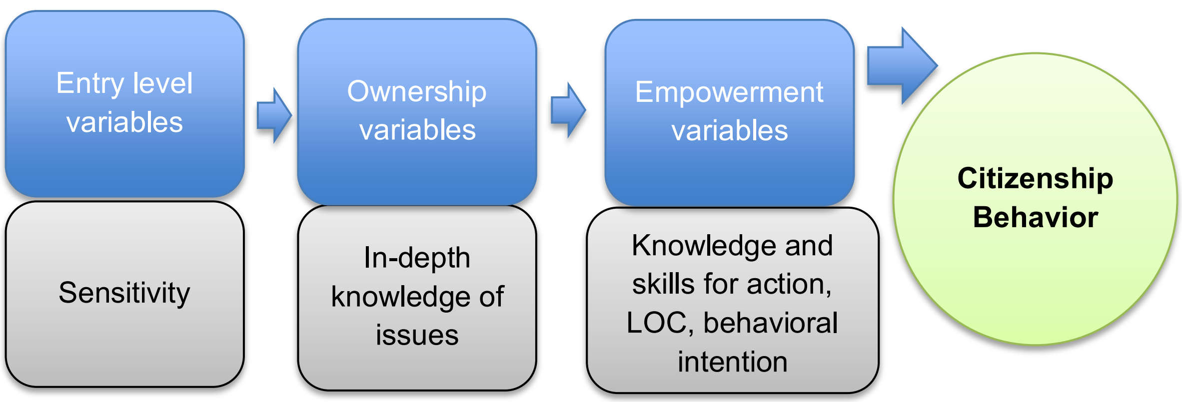


Figure 1: Environmental Citizenship Model laid out by Hungerford & Volk (1990)

Entry level variables can be described as basic sensitivity and knowledge about environmental issues. These variables must be addressed to establish a level of awareness of and baseline sensitivity to the environment. Once established, the model moves to ownership level variables, where people develop deeper knowledge and understanding of specific issues and begin to develop a personal investment in a healthy environment. Once these variables are met, the final stage consists of empowerment level variables, which moves beyond knowledge of problems into knowledge of strategies and solutions for solving and mitigating environmental problems. People at this level have a strong desire and the ability to act on their behaviors and expect well-proven strategies to work for them (Locus of Control, LOC in Figure 1).

Citizen Science and Environmental Education Overlaps

Frameworks from both Citizen Science and Environmental Education suggest that the depth of exposure results in deeper and more advanced outcomes. The participant involvement spectrum (Bonney et al., 2009a) shows how the scale of the role of citizens in scientific research can affect the type of citizen science project (Table 2).

Table 2

Model of CS participation linked to Potential Appropriate Outcomes (Smaldone, 2018)

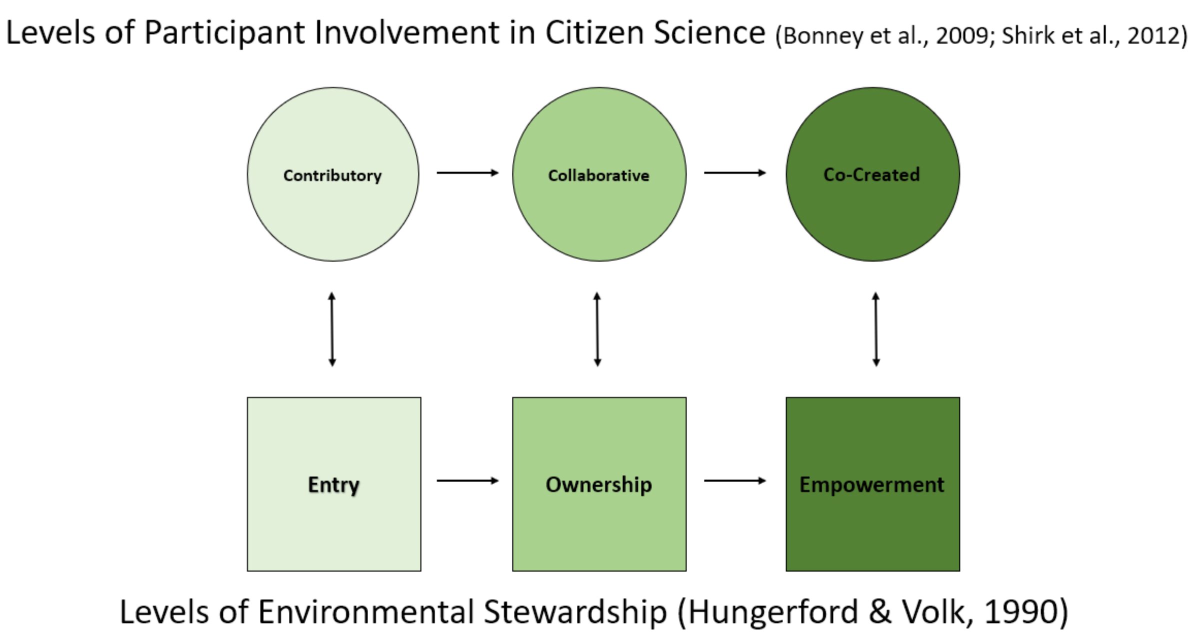
CS Project Type	Engagement & Time Commitment	Hungerford & Volk's model of Responsible Environmental Citizenship	Potential Appropriate Outcomes to Target (Bonney, et. al., 2009a; Friedman, 2008; NRC, 2009)
Contributory	Low level	Entry level variables	1) Interest; appreciation; engagement 2) Awareness; Limited knowledge—related to resource (water quality, etc.)
Collaborative	Moderate level	Ownership level variables	1) Increased interest; appreciation; engagement 2) Awareness; Limited knowledge—related to resource, & science process 3) Identity (attitudes; confidence; personal "investment", etc.) 4) Skills—related to procedural steps in CS projects (data collecting, etc.)
Co-Created	High level	Empowerment level variables	1) Increased interest; appreciation; engagement 2) Increased knowledge & understanding—related to resource, & science process (moving towards scientific literacy) 3) Increased Identity (attitudes; confidence, etc.) 4) Behavior & Skills—intentions & behaviors related to project & science (participating in other CS; conservation, etc.)

More citizen involvement in the creation of the research (Co-Created) means greater investment, knowledge, and action from the citizens (Bonney et al., 2009a; Shirk et al., 2012).

This parallels the Empowerment-level variables of Hungerford & Volk's (1990) continuum, where people are empowered to research and suggest solutions. Working backwards, the Collaborative level ties to Ownership through creating a sense of collaboration and value for the citizen. The Contributory element pairs well with Entry-level variables, where citizens are interested in a problem, but are simply contributing to a project to learn more about it, rather than really taking ownership over the research design and question. Each level of participation in the citizen science model parallels the levels of environmental citizenship (Figure 2) (Bonney et al., 2009a; Hungerford & Volk 1990; Shirk et al., 2012).

Figure 2:

Parallels between participant involvement and level of environmental citizenship.



From the environmental education literature, one of the elements most likely to positively affect outcomes is active and experiential engagement with real-world environmental problems. Specifically, issue-based, project-based, and investigation-focused programs commonly achieved desired outcomes (Stern et al., 2014). Citizen science has the potential to incorporate all of these qualities and easily integrate them into environmental education.

Additionally, at least one paper has proposed using the environmental citizenship model from Hungerford & Volk (1990) to strategize for citizen science (Jørgensen & Jørgensen, 2014). These researchers propose loose strategies for connecting citizen science to environmental citizenship through three main ideas. These broad concepts are collectiveness (recognizing and participating in the collective, collaborative, and communal nature of citizenship and working toward a common good), situatedness (CS learning needs to be embedded in the daily lived experience and social and physical environment), and connectedness (CS should help participants connect their data to structural and systemic roots of environmental problems). The authors leave the implementation of these concepts in practice up to the program designer and recognize the need for further scholarly elaboration on this model. It is also important to note that these three concepts do not follow a spectrum like Hungerford & Volk’s 1990 model of environmental citizenship. Jørgensen & Jørgensen (2014) drew some natural connections between citizen science and Hungerford & Volk’s model (1990) but did not include a novel or even modified framework specific to citizen science.

The following six categories of individual learning outcomes are the ones identified in Phillips et al. (2018). This is one of the first major papers to attempt to understand the evaluation landscape of citizen science and has since been used to develop the DEVISE (Developing, Validating, and Implementing Situated Evaluation) project to unify CS evaluation with validated survey instruments (discussed more in the Method chapter). This project will utilize some of the learning outcomes from Phillips et al. (2018) and some of the associated survey items of the DEVISE instruments. Since this project will draw from that framework, and the surveys developed from it, we will define these CS learning outcome categories.

Interest in Science and the Environment can be viewed as the degree of relevance that someone assigns to an aspect of science or the environment. Interest is not necessarily linked to attitude or behavior change but can be a useful outcome metric for less formal and one-off citizen science experiences.

Self-efficacy reflects the participant's own beliefs regarding how capable they are related to participating in or successfully completing a given activity (Bandura, 1982). In science learning and citizen science, self-efficacy is important as a factor in environmental citizenship, as a measure of perceived confidence (Berkowitz et al., 2005). People who feel more effective at a given task are more likely to persist in it, which is an important outcome for the long-term viability of citizen science projects (Phillips et al., 2018).

Motivation in relation to citizen science is the goal-driven desire to achieve a certain scientific or environmental activity. In citizen science there may be captive audiences such as school groups that may not have any particular motivations, but other participants can have varied motivations for participation in citizen science, including the desire to learn, contribute to science, have fun, meet new people, and others (Phillips et al., 2018)

Content, Process, and Nature of Science Knowledge simply refers to knowledge around different aspects of science. Content is generally the topic the project is about (water, birds, air quality, etc.) and is a more basic form of knowledge. Process knowledge refers to the understanding of the scientific process (hypothesis, observation, analysis, etc.), while the nature of science knowledge is more epistemological, focusing on how science knowledge is generated. Topics within this might include empiricism, validity, and social and cultural influences (Phillips et al., 2018).

Skills of Science Inquiry is a closely related construct to science knowledge but does have important differences. This construct refers to specific aspects of inquiry and actually doing science, beyond knowledge. These concepts are universal to practicing science and are not content-specific. Examples of this can be understanding how hypotheses can be made and tested, analyzing and graphing data, assessing validity and accuracy, and interpreting and disseminating results (Phillips et al., 2018).

Behavior & Stewardship are considered to be the “holy grail” of citizen science (and environmental education) outcomes, based on frameworks from both citizen science and environmental education. A far-ranging goal, the idea is to instill new behaviors and a stewardship ethic in participants, ultimately resulting in increased participation in restoration, and community and civic action. As seen through the frameworks described above (Hungerford & Volk, 1990; Shirk et al., 2012) this construct gets into higher levels of environmental citizenship that focus on deep knowledge, action, and confidence about solving environmental problems.

Combining environmental education and citizen science may have great potential to affect positive outcomes in learners due to similarities in their frameworks related to programmatic outcomes. Though citizen science has been studied for several decades, the need for research on outcomes of participation remains great, especially in youth, 4-H and Extension education. Further research on how different characteristics of different citizen science programs and levels of exposure affect outcomes is still needed. This project, by evaluating the outcomes of citizen science in a youth 4-H setting, can provide new and important information to inform future program development.

Chapter 3: Methodology

Design:

Citizen science generally lacks research on the different learning outcomes related to different types of CS programs. Research barriers include differing goals and methods between sites and projects, as well as the lack of time and knowledge for practitioners to conduct in-depth research and evaluation (Phillips et al., 2012, 2018). This study uses a quantitative pre-post program evaluation research design to explore several constructs or potential individual learning outcomes (Phillips et al., 2014).

Despite the differing goals of citizen science programs, common outcomes have been summarized by Phillips et al., (2018) and in-depth program evaluation guides have been created based on that framework. Additionally, the Cornell Lab of Ornithology created the DEVISE (Developing, Validating, and Implementing Situated Evaluation) scales, which are survey instruments containing validated questions for assessing various citizen science individual learning outcomes (Cornell Lab of Ornithology, n.d.). These scales contain questions for each of the outcome areas or constructs discussed in the literature review. Research that has used these scales are mainly evaluations of some type of environmental citizen science project, although the more general “Efficacy for Learning and Doing Science” scale has also been used in a health education citizen science project (Peterman et al., 2018). Since these scales were created by the Cornell Lab of Ornithology, it is fitting that they’ve been used with environmental and biological citizen science projects. Studies have looked at various learning outcomes related to the topics of insects, sharks, urban gardens, phenology, and general biology and ecology projects, but have used the same DEVISE scales to assess outcomes. Most studies focused on a single construct, often efficacy, but a few have used multiple scales to identify multiple outcomes from one program (Flagg, 2016; Halliwell, 2019; Hsu et al., 2020; Lynch et al., 2018; Merenlender et al., 2016; Phillips, 2017; Sandhaus et al., 2019).

Positionality

This study is part of a larger Citizen Science project involving a number of partners in the Morgantown, WV area, primarily in the Decker's Creek watershed. While their experiences differed, they were all ultimately tied to Decker's Creek. My research, out of need for a larger sample size, moved south to the West Fork River watershed in Jackson's Mill, WV, where the state 4-H summer camp is based. My research focused on middle school and high school-aged youth from around the state who attended Jackson's Mill for a week-long summer camp experience. Our citizen science project was one of several activities that campers chose to participate in during their week at camp.

In my role as a graduate assistant, I revised lesson plan content for this new group of campers. My primary roles over the summer were training and supporting the Extension camp counselors, and survey data collection from the youth participants. The actual instruction and engagement of the lessons was done by 2 counselors hired by 4-H Extension staff (in consultation with Dr. Smaldone) to work at Jackson's Mill for the duration of the summer. Dr. Smaldone and I spent several hours walking through the lessons with the counselors and were available for questions and guidance as camps began. This separation between researcher and counselor will hopefully reduce any bias in the surveys that would result in a closer relationship between myself and the campers.

Site

This research took place at Jackson's Mill in Weston, West Virginia. Due to a legacy of extraction, West Virginia faces a number of (often interrelated) social and ecological problems. The 2020 US Census reports that only 21.3% of West Virginians have a bachelor's degree or higher, compared to 36% nationwide. This measure of educational attainment represents only one way of understanding education and knowledge but shows the West Virginian educational system is producing lower than average results. Alternative and supplemental informal learning opportunities can provide novel and engaging educational experiences that may be useful in raising this number (Bonney et al., 2009a; Shaw et al., 2004; Stocklmayer et al., 2010).

The water quality data collected in this project were from the West Fork River, which drains north into the Monongahela, and eventually into the Ohio and Mississippi Rivers. The West Fork unfortunately has been negatively impacted by the gamut of legacy and active pollutants: acid mine drainage (AMD) from abandoned coal mines in the region, metal pollution from industrial uses, excessive sedimentation and runoff from logging, agriculture, mining, and construction; sewage from under-maintained municipal and personal sewer and septic systems, illegal dumping of trash, and hydraulic fracturing (fracking) wastewater (West Virginia Department of Environmental Protection, 2014; United States Environmental Protection Agency, 2002).

The West Fork River does have a small volunteer group called Guardians of the West Fork River that is questionably active currently. Historically, the group has been involved with dam removal/preservation, river cleanups/paddling events, the development of the West Fork River Water Trail, and some Acid Mine Drainage treatment (Christ, 2023). This group does not have an active website, but occasionally posts and shares information and events on Facebook (Guardians of the West Fork River, n.d.). It is unclear whether this group gathers their own water data or uses the data provided by the West Virginia Department of Environmental Protection (WVDEP). To my knowledge, the data gathered this summer will be the first regular water quality data gathered by non-professional community members (i.e., citizen scientists), and may inspire greater action around watershed issues. This citizen science program has been partially adapted from the Friends of Deckers Creek’s CS program, a watershed group near Morgantown, who worked with student groups using these activities in previous project years. The most recent adaptation of the curriculum activities was honed for relevance to 4-H campers at Jackson’s Mill during Summer 2022.

Citizen Science Curriculum

The intervention consisted of a 4-lesson version of the citizen science program with a slight variation based on their camp schedule. The activities were designed to move participants along Hungerford & Volk's 1990 Environmental Citizenship Model, from awareness-level concepts to stewardship-level concepts, while also exposing participants to different stages of the scientific process. Each lesson included water quality sampling. Lesson 1 (Observation & Citizen Science) focused on defining science, understanding citizen science, and understanding different ways to assess water health (chemical vs. physical, etc.). Lesson 2 (Watershed Discovery) explored how research questions fit into citizen science, the watershed concept and how pollution can affect an entire watershed. Lesson 3 (Data & Analysis) moved along to the idea of analyzing and visualizing data they had collected so far, and how to draw conclusions from that data. The last lesson, Lesson 4 (Restoration & Stewardship) sought to wrap up the series of activities by taking conclusions from the data and applying them to potential restoration and stewardship activities to improve the health of the West Fork at camp. Campers were also exposed to some existing stewardship and restoration activities that previously occurred at the site. A summary of the lessons, their topics, and the CS/EE skills they address are depicted in Table 3 below.

Table 3

Lesson Summaries and Skills

Lesson	**Main Topics**	**CS Skills** (Step in Science Inquiry Model)	**EE Skills**
1: Observation & Citizen Science	What is Science?, Intro to CS, Stream Assessment, Data Collection	Observation (Step 1), Data Collection (Step 3)	**Entry-Level** (interest, limited knowledge), **Ownership** (increased interest, skills, investment)
2: Watershed Discovery	Research Questions, Hypotheses, Watersheds, Data Collection	Research Questions (Step 2), Data Collection (Step 3)	**Entry-Level** (interest, limited knowledge) & **Ownership** (increased interest, knowledge, skills, investment)
3: Data & Analysis	Importance of Data, Analyzing Data, Data Collection	Data Collection (Step 3), Analysis (Step 4)	**Entry-Level** (interest, limited knowledge) & **Ownership** (increased interest, knowledge skills, investment)
4: Restoration & Stewardship	Problem Identification, Restoration Techniques, Opportunities for Stewardship, Data Collection	Data Collection (Step 3), Analysis (Step 4), Dissemination/Application (Step 5)	**Entry-Level** (interest, limited knowledge), **Ownership** (increased interest, skills, investment), **Empowerment** (Knowledge of environmental strategies, intention to act, in-depth knowledge)

This curriculum was initially designed for a different context but was modified for the 4-H camp setting and audience. All watershed content was place-based around the West Fork

River. The structure was also changed slightly due to time constraints provided by the camp's scheduling. Instead of a "full" camp week of 5, 90-minute lessons, different camp weeks received slightly different lesson formats based on their unique schedules - something largely in the control of our 4-H partners, so flexibility was key. The camp schedules are displayed in Table 4.

Table 4

Number of Participants and Description of Lessons

Week	Number of Participants (Pre-Surveys)	Lessons
1 - Older Members Conference (OMC)	40	4 lessons at 45 minutes each
2 - Harrison County Camp	110	4 lessons at 1 hour each
3 - Lewis County Camp	12	3 lessons at 1 hour each (Lessons 3 and 4 combined into 1, hour-long lesson)
4 - Alpha I Camp	4	4 lessons at 1 hour each
5 - Alpha II Camp	8	4 lessons at 1 hour each

Sample

While we were originally expecting 13–19-year-old participants, our actual age range went from 9-21. After data cleaning, the sample consisted of 12–21-year-old participants in summer camp at Jackson's Mill. Though WVU Extension and 4-H have been running outdoor recreation and education activities at Jackson's Mill since 1921, to the best of our knowledge this was the first intentionally designed citizen science project to directly involve campers. Students (or their parents) attending camp had the option to register for this program (series of activities) like any other 4-H class they would want to do during their week at camp.

In order to participate in the study (i.e., completing the pre and post surveys), participants needed to provide parental consent and camper assent through Extension staff during camp registration, and then actually attend the lessons. Non-consenting participants were still able to take part in the activities but did not fill out the surveys.

Measures

Data were collected using a pre and post engagement paper survey given directly to campers. The surveys were approved by the WVU Institutional Review Board, IRB Protocol #1903511420. The survey was primarily developed by Dr. Smaldone, incorporating questions from several existing citizen science evaluation tools, including the DEVISE instruments mentioned in the introduction and literature review which are based on the citizen science learning outcome framework (California Academy of Sciences, 2015; Kraemer & Zint, 2014; Phillips et al., 2018). These surveys have several items per outcome category and have been used in other parts of the larger overall study by Dr. Smaldone. The surveys can be found in Appendix A.

These surveys were part of a larger study and had questions addressing several other constructs that are not relevant to this specific research. The specific survey items related to each of the research questions are detailed below in Table 5.

Table 5

Corresponding Survey Items

Outcome Area	Pre-Survey Item	Post-Survey Item	Question
RQ 1: Interest	15a	8a	I enjoy learning science.
	15b	8b	I want to understand how things in the environment work
	15c	8c	I think science is interesting
	15d	8d	Learning science helps me understand about the environment
	15e	8e	One day I would like a job that involves using science
RQ 2: Knowledge	12	3	Ultimately, where does water usually end up after it enters a storm drain on a street?
	14a	5a	Which of these is a type of pollution that hurts Deckers Creek? Fertilizer running off farm fields into the creek.
	14b	5b	Which of these is a type of pollution that hurts Deckers Creek? Acid mine drainage pollutants caused by abandoned mines
	14c	5c	Which of these is a type of pollution that hurts Deckers Creek? Raw sewage from household pipes.
	14d	5d	Which of these is a type of pollution that hurts Deckers Creek? Illegal dumping of trash into the creek.
	15f	8f	Knowledge of science will help me conserve the environment.
	15g	8g	I am familiar with how scientists use data to study water quality.
	15h	8h	I can collect data that is valuable to scientists studying water quality.
	15i	8i	Citizen scientists can contribute to science.
	15j	8j	I am confident in my ability to contribute to scientific projects or research
	15k	8k	I can contribute to a citizen science project
	16a	7a	I can ask a question that can be answered by collecting scientific data.
	16b	7b	I can accurately record scientific data.
	16c	7c	I can collect scientific data using a standardized protocol.
	16d	7d	I can use existing scientific data to answer a scientific research question.
	16e	7e	I can conduct appropriate analyses using scientific data.
	16f	7f	I can effectively communicate scientific findings to others.
	N/A	10a	Participating in this project has improved my understanding of how scientists gather and use datato monitor water quality.
RQ 3: Stewardship	15l	8l	I am aware that my actions can impact water quality and the environment.
	15m	8m	I am capable of making a positive impact on local streams and waterways.
	17a	9a	I know how to help clean up or take care of a local stream, river, or lake
	17b	9b	I know how to participate in an environmental restoration activity (such as planting trees or removing invasive plants)
	17c	9c	I know how to talk to others about ways they can protect a local creek or lake.
	N/A	10e	Participating in this project has made it more likely that I will participate in other projects related to improving the environment.
	N/A	11a	Since my participation in the West Fork River Citizen Science project I have talked about the project with others (who were not involved in the project).
	N/A	11b	Since my participation in the West Fork River Citizen Science project I have made changes in my daily life related to improving water quality based on what I've learned from the project
	N/A	11c	Since my participation in the West Fork River Citizen Science project I have used social media to communicate or share with others about the project.
	N/A	11d	Since my participation in the West Fork River Citizen Science project I have searched for more information about water quality in general
	N/A	11e	Since my participation in the West Fork River Citizen Science project I have searched for more information about how I can improve water quality near where I live.

Data Collection & Analysis

The pre-survey was administered in person via paper questionnaires at the beginning of the week of lessons for campers prior to any engagement around citizen science. The post-survey was administered immediately following the last lesson of the week (also via paper and in-person). The physical surveys were collected by me and subsequently entered into Google Sheets in late summer 2022.

After data were entered, it was then imported to IBM SPSS Version 27 for analysis. The data were analyzed in three different ways. For the items that were matched on the pre and post surveys, analysis was done with paired t-tests to look at differences in mean scores (on a Likert scale of 1-5, 1 being "strongly disagree", 5 being "strongly agree"). Since we are comparing pre-surveys and post-surveys from the same individuals, paired t-tests are appropriate.

Another analysis employed was the McNemar test, used to compare and understand the change in pre and post proportions for a dichotomous nominal variable (in our case correct/incorrect). As opposed to a traditional chi-square test, the McNemar test is a non-parametric test specifically designed for repeated measures. This test was used on questions where we are looking for a correct answer (Pre-Survey items 11 and 13) to assess the Knowledge outcome related to water quality. This analysis assesses the changes in the number of correct responses from pre to post.

The last technique used for understanding the data was descriptive frequencies. We looked at this for several items asked only on the post-survey, and they were measured on a 1-5 Likert scale. Since these questions did not have a counterpart on the pre survey we could not analyze them with paired t-tests. We can gain an understanding of these questions by looking at frequency distributions and descriptive statistics.

Chapter 4: Results

A total of 174 youth participated in the activities this summer. By the end of the camp season, we received 174 pre-surveys and 147 post-surveys. The pre- and post-surveys numbers were not equal because some campers were not present at the time of the post-survey (for various reasons – illness, left camp early, chose another activity, etc.). Since all campers took the pre-survey, our pre-survey response rate was 100%. The post-survey response rate was 84.5%. From these, we had 136 paired sets of pre- and post-surveys. After removing several surveys for incompleteness or otherwise inaccurate surveys (i.e., surveys with all 5s circled), 125 pairs of surveys were used for analysis, resulting in a final adjusted response rate of 92% (from the overall surveys pairs of 136).

Of the 125 respondents used in analysis, 35% of the youth identified as male, 57% as female, 1.6% as another gender, and 5.6% preferred not to disclose. Ages ranged from 12 to 21, with a mean age of 16, representing a slightly older demographic group than was assumed would participate (Table 6).

Table 6

4-H Camper Age Frequency Distribution

Age	Frequency	Valid Percent
12	2	1.6
13	13	10.7
14	24	19.7
15	16	13.1
16	22	18.0
17	18	14.8
18	12	9.8
19	6	4.9
20	5	4.1
21	4	3.3
Total	122	100.0

Similarly, grade levels ranged from 6th grade to college seniors, with mean and median between 10th and 11th grade. The findings related to ethnicity and race revealed an overwhelmingly White-identifying sample at 95%, with a few individuals identifying as Hispanic or Latino, Native American, or a combination of ethnic backgrounds including Black/African American and Asian. The last demographic characteristic analyzed was state of residence, with 96% of the sample residing in West Virginia.

Interest in Science and the Environment

The outcome area of Interest in Science and the Environment was measured only through paired t-tests with items 15 (a-e) on the pre-survey, and 8 (a-e) on the post-survey. The results are depicted in Table 7. Three of the five Interest-related items showed a significant ($p<.05$) positive change, with an average mean score increase of 0.21 on a 5-point scale.

Table 7

Interest Outcome Paired t-Test Summary

Outcome Area	Pre-Survey Item	Question	Mean Score Difference	t-value	Significance (* = p<.05)
Interest	15a	I enjoy learning science.	0.232	-3.146	*
	15b	I want to understand how things in the environment work.	0.315	-4.220	*
	15c	I think science is interesting.	0.185	-2.197	*
	15d	Learning science helps me understand about the environment.	0.113	-1.339	
	15e	One day I would like a job that involves using science.	0.185	-1.945	

Knowledge of conducting science, water quality, and citizen science

The outcome area of Knowledge of conducting science, water quality and citizen science was measured with paired t-tests, McNemar tests, and post-only descriptive analysis.

Beginning with the paired t-tests, we analyzed 12 items related to Knowledge, all of which showed a very significant (p<.001) positive change in mean scores from pre to post. The average mean score difference from pre to post was 0.61 on a 5-point scale, with item 15g increasing nearly 1.5 points (Table 8).

Table 8

Knowledge Outcome Paired t-Test Results

Outcome Area	Pre-Survey Item	Question	Mean Score Difference	t-value	Significance (p<.05)
Knowledge	15f	Knowledge of science will help me conserve the environment.	0.331	-4.418	*
	15g	I am familiar with how scientists use data to study water quality.	1.476	-12.670	*
	15h	I can collect data that is valuable to scientists studying water quality.	1.008	-8.263	*
	15i	Citizen scientists can contribute to science.	0.492	-5.569	*
	15j	I am confident in my ability to contribute to scientific projects or research.	0.565	-6.460	*
	15k	I can contribute to a citizen science project.	0.435	-4.941	*

16a	I can ask a question that can be answered by collecting scientific data.	0.431	-5.754	*
16b	I can accurately record scientific data.	0.569	-6.897	*
16c	I can collect scientific data using a standardized protocol.	0.439	-5.928	*
16d	I can use existing scientific data to answer a scientific research question.	0.496	-6.241	*
16e	I can conduct appropriate analyses using scientific data.	0.537	-7.415	*
16f	I can effectively communicate scientific findings to others.	0.561	-6.862	*

We also used a McNemar test to understand the difference in the proportion of correct answers to other Knowledge-related multiple-choice items on the pre-post surveys. By recoding these multiple-choice question responses into a correct/incorrect answer binary, we can understand the change in responses from pre to post. The test for the Knowledge-related item regarding where water goes in a storm drain did show a significant ($p = <.001$) change in the proportion of correct answers from pre to post. Thirty-seven individuals who responded incorrectly on the pre-test answered correctly on the post survey, and 48 individuals answered correctly both times (Tables 9 and 11).

Table 9

Where does water end up after entering a storm drain? (Pre-Survey Item 3)

	Post	
Pre	Correct	Incorrect
Correct	48	8
Incorrect	37	32

Analysis of four other multiple choice water quality Knowledge-based items found no statistically significant difference in the proportion of correct responses pre and post intervention for items related to pollution types in the watershed, including fertilizer, acid mine drainage, raw sewage, and trash dumping (Crosstabs depicted in Tables 10a-d and 11). Despite the lack of statistical significance, all of these items had more correct answers in the post than the pre, so the change was positive, although not significant ($p>.05$).

Table 10a

Which of these is a type of pollution that hurts the West Fork River? Fertilizer running off farm fields into the creek. (Pre-Survey Item 5a)

	Post	
Pre	Correct	Incorrect
Correct	74	12
Incorrect	21	14

Table 10b

Which of these is a type of pollution that hurts the West Fork River? Acid mine drainage pollutants caused by abandoned mines (Pre-Survey Item 5b)

	Post	
Pre	Correct	Incorrect
Correct	78	12
Incorrect	17	14

Table 10c

Which of these is a type of pollution that hurts the West Fork River? Raw sewage from household pipes (Pre-Survey Item 5c)

	Post	
Pre	Correct	Incorrect
Correct	60	16
Incorrect	18	27

Table 10d

Which of these is a type of pollution that hurts the West Fork River? Illegal dumping of trash into the creek (Pre-Survey Item 5d)

	Post	
Pre	Correct	Incorrect
Correct	97	9
Incorrect	11	4

Table 11

McNemar Test Summary for Knowledge Outcomes

	Where does water end up after entering a storm drain?	*Which of these is a type of pollution that hurts the West Fork River?* ***Fertilizer*** *running off farm fields into the creek.*	*Which of these is a type of pollution that hurts the West Fork River?* ***Acid mine drainage pollutants*** *caused by abandoned mines.*	*Which of these is a type of pollution that hurts the West Fork River?* ***Raw sewage*** *from household pipes.*	*Which of these is a type of pollution that hurts the West Fork River?* ***Illegal dumping of trash*** *into the creek.*
N	125	121	121	121	121
Chi-Square[a]	17.422	1.939	.552	.029	
Asymp. Sig.	**.000**	.164	.458	.864	
Exact Sig. (2-tailed)					.824[b]

a. Continuity Corrected

b. Binomial distribution used.

The last way of assessing Knowledge outcomes was through a question asked only in the post-survey. We did not ask this on the pre-survey and thus had no comparison, so we analyzed it with descriptive frequency distributions to understand the responses. With a mean of 4.07, participants “agree” on average that participating has improved their understanding of how scientists gather and use water quality data, a central theme of the lessons. Almost 80% of respondents agreed (reported 4 or 5) and only 2.4% disagreed with the idea (Table 12).

Table 12

Knowledge Outcome Post-Only Statistics

Outcome Area	Question	Mean	Median	Standard Deviation	Agreement (%)	Neutral (%)	Disagreement (%)
Knowledge	Participating in this project has improved my understanding of how scientists gather and use data to monitor water quality.	4.07	4.00	0.85	79.2	18.4	2.4

Beliefs and/or actions about Stewardship

The last category of outcomes, beliefs and/or actions about Stewardship, was measured with paired t-tests and post-only descriptive frequencies.

Of the six pre-post items analyzed with paired t-tests, four showed a statistically significant positive change. The other two showed a positive change, but were not statistically significant ($p<.05$, Table 13). The average score increase for these items was 0.31, which was less than the average score increase for Knowledge-related items.

Table 13

Stewardship Outcome Paired t-Tests

Outcome Area	Pre-Survey Item	Question	Mean Score Difference	t-value	Significance (* = p<.05)
Stewardship	15l	I am aware that my actions can impact water quality and the environment.	0.073	-.846	
	15m	I am capable of making a positive impact on local streams and waterways.	0.210	-2.232	*
	15n	I care about creeks.	0.145	-1.541	
	17a	I know how to help clean up or take care of a local stream, river, or lake.	0.460	-4.477	*
	17b	I know how to participate in an environmental restoration activity (such as planting trees or removing invasive plants).	0.435	-4.168	*
	17c	I know how to talk to others about ways they can protect a local creek or lake.	0.565	-5.218	*

The six post-only items for Stewardship displayed means ranging from 3 to 4, with an average mean score for all items of 3.37, fairly close to a neutral 3 on the 1-5 scale. Detailed statistics are depicted in Table 14. When looking at agreement levels for these items, more than 75% of respondents agreed (answered with a 4 or 5) that participating in the project "made it more likely that I will participate in other projects to help the environment.” The remaining items had agreement levels in the low 40% range, except the item related to social media use, with just over 30% agreement.

Table 14

Stewardship Outcome Post-Only Statistics

Outcome Area	Question	Mean	Median	Standard Deviation	Agreement (%)	Neutral (%)	Disagree (%)
Stewardship	Participating in this project has made it more likely that I will participate in other projects to help the environment.	4.00	4.00	0.77	73.6	24.8	1.6
	I have talked about the project with others (who were not involved in the project).	3.31	3.00	1.08	44.0	35.2	20.8
	I have made changes in my daily life related to improving water quality based on what I've learned from the project.	3.37	3.00	0.97	43.2	40.8	16
	I have used social media to communicate or share with others about the project.	3.00	3.00	1.14	31.2	35.2	33.6
	I have searched for more information about water quality in general.	3.26	3.00	1.08	44.8	31.2	24.0
	I have searched for more information about how I can improve water quality near where I live.	3.26	3.00	1.05	41.6	37.6	20.8

Chapter 5: Discussion

Overall, the results illustrate an overall success of our activities—while many studies focused on learning outcomes find evidence for positive change through qualitative and quantitative methods (Marcum-Dietrich et al., 2021; Peter et al., 2019), it is less common to have so many items show statistically significant positive changes (Cooper et al., 2017; Peter et al., 2019). This demonstrates the effectiveness of a combined CS and EE approach to increasing Interest in science and the environment; Knowledge of water quality, science, and citizen science; and Stewardship intentions. Strategically developing the lessons to focus specifically on these outcomes, combined with knowledgeable and well-trained counselors, was a recipe for success. It also highlights some potential areas to modify in future projects.

Before discussing each outcome area in detail, I did want to take a moment to address the difference in practical versus statistical significance of the results. Gradations of significance exist within these results – even testing at .05 α level, several items showed significance at much lower α levels. While we had many statistically significant results, some of the changes in actual mean scores from pre to post were small. However, because our sample size was relatively small ($n = 125$) and we still saw statistical significance, we can consider all statistically significant results important or practically significant (Privitera, 2015). The flipside of that is also true – there were many items that did not show statistical significance that still displayed a positive score change (exceptional score changes are identified and discussed). In fact, every single item analyzed with each different test displayed a positive score change. In terms of practical significance, this indicates that there are no areas of the lessons that need urgent restructuring or are negatively impacting learning outcomes (McLean & Ernest, 1998). Considering the lessons as a suite of activities (as they were planned that way) and the outcome areas holistically, there is positive change across the board, showing the practical value of the lessons.

Acknowledging the role of the participants' background is also important in understanding these results (Heck et al., 2012). Many campers who participated in this study were regular 4-H campers and participants in nonformal learning. Since they are more likely to have encountered learning experiences in similar settings, they may be showing smaller positive changes than other groups who are learning more new information through these lessons. On the other hand, youth who have never participated in 4-H camp or were not very interested in watersheds may start with lower levels of knowledge and interest and may show a larger score increase. Since we were unable to run a control or non-4-H group in this study, we do not yet know the extent of how participation in 4-H specifically effects the educational outcomes of participation in CS/EE. Heck et al.'s (2012) work indicates that exposure to science programming in 4-H may be associated with a long-term increased interest and participation in science learning, and future research should be done to understand the long-term effects of this program on participants. It's critical to keep the audience in mind when designing any type of nonformal learning, and this curriculum should be adjusted for the target audience (Phillips et al., 2018; Grier & Bryant, 2005).

With those ideas in mind, each outcome area will be discussed in detail below.

Interest in Science and the Environment

The three of five Science Interest-related items that had significant positive change (average score increase of .22 on a 5-point scale) encapsulated ideas related to enjoyment and interest in science, which are relatively basic concepts compared to other outcome areas (Bonney et al. 2009a; Hungerford & Volk, 1990; Phillips et al., 2018). These ideas were not directly targeted in the lessons but may be related to the self-selection issue of this research. However, it appears that exposure to this curriculum led to an increase in Interest outcomes in participants.

On the other hand, the item related to wanting a job that involves science did not show a statistical change. We acknowledge that these lessons did not really target careers in a meaningful way – it was not a priority for this audience given the time available. Future iterations could bring in professionals or discuss careers relating to science, water, and stream restoration to address this. Due to time restrictions in this setting, it was not possible, but should be explored in future research and other programs targeting the outcomes associated with the “Empowerment” level of Hungerford & Volk’s model, especially for participants approaching the end of high school or college and preparing to enter the environmental field.

Interest or engagement is one of the most measured outcomes in citizen science projects (Phillips, 2017). While Toomey and Domroese (2013) found an increase in interest of general community environmental issues, we did not have a comparable survey item. Occasionally, studies looking at CS outcomes related to attitudes ask similar questions about interest in science and the environment, and generally find positive changes or improved attitudes towards science, citizen science, and scientific topics (Garibay Group, 2015; Haywood, 2016; Peter et al., 2019; Sickler, et al., 2014;). Kountoupes & Oberhauser (2008) documented the ability of their monarch butterfly monitoring project to spark youth interest in real science. A contrasting study by Druschke and Seltzer (2012) found no positive changes in attitudes and interest about science and the environment in a bee CS project, and even noted some statistically insignificant negative changes in attitudes toward science following CS participation.

Knowledge

Of the three outcome areas analyzed in this study, the area of knowledge showed the highest proportion of statistical significance (12 out of 12 paired t-test items (average score increase of .55 on a 5-point scale), 1 of 5 McNemar tests (all others showed positive growth), and the post-only item averaging a 4.07 (just above “agree”) and an agreement percentage of 79%. As discussed in the literature review, Knowledge (and awareness) of the environment and environmental issues is a foundational element of Hungerford & Volk's 1990 model and is a prerequisite to deeper knowledge and stewardship action. Since the lessons were designed to target these earlier phases of that model more heavily, it is vindicating to see the results support that.

While the item asking about where water goes after entering a storm drain did show a positive significant McNemar statistic, analysis of 4 other multiple-choice water quality Knowledge-based items found no statistically significant differences in the proportion of correct responses pre and post intervention. These items are related to pollution types in the watershed, including fertilizer, acid mine drainage, raw sewage, and trash dumping. Despite not achieving statistical significance, the number of correct responses still increased from pre to post for all of these items which is encouraging. In future camps, more discussion or activities specifically related to these impacts could be developed to attempt to address this. As more data are gathered by campers, specific water issues might be discovered that can directly connect to future lessons.

The post-only item for the Knowledge outcome of "understanding of how scientists gather and use data" also had a high mean score and agreement level (4; 79% agreed). This idea was central and explicit in the lessons, so it's not surprising that we found such a high level of agreement among the participants.

These results are consistent with essentially all of the previous literature that suggests real knowledge gains can occur from participating in citizen science (Brouwer et al., 2018; Crall et al., 2012; Jordan et al., 2011; Peter et al., 2019). Looking at Kaplan's 2020 thesis, we see similarly high levels of knowledge gains relating to water quality and citizen science, and a similarly lower level of knowledge of the scientific method. Because that research was based off a nearly identical curriculum, it adds reinforcement to our findings.

Stewardship Behaviors and Intentions

Under the learning outcome of Stewardship, compared to Knowledge, we saw a slightly lower level of significance in the paired t-tests (4 of 6 items tested were significant, $\alpha = .05$; average score increase of .42), and lower mean scores and levels of agreement in the post-only items (6 items, mean of all mean scores 3.36, mean of agreement levels = 46%). Overall, it is apparent that Knowledge outcomes increased more than Stewardship over a week of camp, an idea that falls in line with the Environmental Citizenship and CS Levels of Public Participation frameworks (refer back to Table 1 and Figure 1) (Bonney et al., 2009a; Hungerford & Volk, 1990; Shirk et al., 2012) as well as existing studies (Bonney et al., 2009b; 2019; Jordan et al., 2011).

The items for Stewardship related to how personal actions can impact water quality and the environment. Based on our theoretical frameworks and research, we understand that moving people along the spectrum to stewardship action over short periods of time like a week of camp is unlikely (Hungerford & Volk, 1990; Bonney et al., 2009a; Jordan et al., 2011, Peter et al., 2019). There are several potential options for addressing this. An obvious route would be to increase the amount of time campers participate in the lessons, although this is constrained by camp schedules. Another option might be to focus more on specific Stewardship outcomes in the lessons, and an ideal scenario would have campers participate in such stewardship activities (e.g., tree planting, trash pickup, and stream bank restoration). If this project was evaluated on a long-term basis looking at campers returning each summer, it would be interesting to see how the Stewardship numbers change with increased exposure. We know from the literature (Stern et al., 2014) that project-based learning is an effective methodology for EE, so doing an actual restoration project could increase Stewardship outcomes by providing specific training and empowering participants (especially on the items related to capability and knowledge of restoration projects).

The only Stewardship item to achieve higher levels of agreement was “intention to participate in similar environmental projects” and it had a strong level of agreement (74% of respondents agreed; mean = 4). The other Stewardship items related to actual behavior changes received similar agreement levels—and all were fairly neutral or slightly positive (just over 3, which was the mid-point on the scale). These findings provide evidence that supports previous research—cognitive (i.e., knowledge) and affective (i.e., appreciation) outcome changes are typically easiest to achieve in one week compared to behavioral changes (Hungerford & Volk, 1990; Jordan et al., 2011; Sickler & Messick, 2012). Additionally, the Stewardship behavior items related to longer-term behaviors that campers most likely would do later (i.e., when at home, after camp ended) did not have very high levels of agreement. This suggests that more exposure to stewardship activities or providing stewardship opportunities during camp may be needed to increase Stewardship outcomes with this program (Kaplan, 2020). Providing some sort of take-home resources at the end of camp or providing local 4-H chapters with this curriculum may improve these longer-term outcomes as well (Garibay Group, 2015).

As mentioned, these results generally fit with the existing research on citizen science outcomes. Although some studies show no stewardship behavior change compared to other outcomes (i.e., Knowledge and Awareness) (Jordan et al., 2011), our study found that intention to participate in similar projects was fairly high. This strong intention of stewardship again aligns with Kaplan’s (2020) thesis focused on a nearly identical curriculum in slightly different setting. It also shows parallels to Ballard et al.’s (2017b) research, focusing on two CS programs in San Francisco. Those researchers found three ways to achieve environmental science agency, a related concept to stewardship. The factors of the projects that led to this agency were identified as rigorous data collection, dissemination to authentic external audiences, and investigating complex socio-ecological systems. In order to expand our Stewardship outcomes, adding additional lessons in these areas may increase these outcomes.

While many CS outcome evaluations have evaluated and found positive stewardship behaviors, Peter et al.'s (2019) systematic literature review found that these were generally more superficial or passive than desired. In our case, this also was true, as items such as "talking about the project" had higher mean scores than the ability to do an actual restoration project. This again connects back to our participants not doing an actual project as part of their lessons. Future research might focus on how the presence of an actual restoration project as part of the curriculum impacts Stewardship outcomes.

Limitations

Because the focus of this research was on one specific citizen science project and set of lesson plans, it is not appropriate to generalize the results to the broader field of citizen science and environmental education. However, this first step in assessing the outcomes of connecting these fields was important to take.

Some methodological limitations include the lack of a control or comparison group. In order to reach the most participants, we decided everyone should be in the treatment group. Additionally, a self-selection bias exists with 4-H campers being able to participate in the sample that may already have a higher baseline level of environmental knowledge or interest. This self-selection also extends to the choice of which classes to participate in while at camp. Those choosing to participate in these lessons may have a higher starting point for interest and knowledge of the environment than a random sample (Whitehead, 1991).

All surveys have a self-reporting bias, and ours are no exception. We're relying on participants to answer honestly. By cleaning data, removing suspicious surveys (i.e., all 5s circled but no written responses), and having some survey items that have correct answers rather than self-reported scales, we're able to reduce this somewhat (Leavy, 2017). During survey delivery, I encouraged honest answers on the surveys and reminded participants that it was not a test and to avoid answering the way they thought they should.

Another limitation was indirect control of the lessons. Though we trained the counselors to lead the lessons in a way aligning with our theoretical backing and goals, there may have been adjustments based on their skills and the demands of the camp schedule.

Implications

The results of this research show the impact of a short-term water quality informal educational experience utilizing citizen science as a platform for environmental education. Our analysis illuminates the extent to which youth's Interest, Knowledge, and Stewardship increased as a result of participation. Our results fit both with the theoretical models and with existing literature, corroborating our findings and the validation of this framework for citizen science program design (Bonney et al., 2009a; Hungerford & Volk, 1990; Jordan et al., 2011; Peter et al., 2019; Sickler & Messick, 2012).

When designing programs for youth, future program managers might use elements of this program to develop their own water quality programs focused on the outcomes they want to achieve. Our results could also impact the way that non-formal (and potentially formal) STEM education is done.

By understanding the outcomes of a short-term, place-based summer camp engagement with citizen science, educators and program managers can better plan, prepare, and optimize their activities for individual learning outcomes.

Future Directions

There are many potential outcomes of participation in citizen science that, while tangential to the three analyzed in this study, were not addressed. To establish a reasonable scope for this study, I focused on three, but our instruments contained additional questions relating to other outcome areas. These data, along with the qualitative data from the surveys, should be more carefully analyzed for a more holistic view of outcomes and explanations of outcomes in this experience.

As mentioned in the limitations sections, the pre-existing disposition to higher (or lower) than average levels of baseline knowledge and interest in watershed issues that 4-H campers have could be another research area. Understanding the ways that the amount of time or participation in nonformal science learning effects learning outcomes of citizen science could be important for extension program planners as they develop suites of educational opportunities for their members. This idea of varying amounts of prior knowledge connects back to the cognitive hierarchy explained by Vaske & Manfredo (2012). Further research investigating how the amount or type of prior knowledge mediates attitude and behavior change in EE and CS settings could be incredibly insightful for program planners.

While we do have some systematic literature review of citizen science learning outcomes (Peter et al., 2019), it would be useful to update these, and potentially create them relevant to water quality specifically. Synthesizing various studies in this area might reveal underlying similarities and inform for better design. Similarly, we might take a cue from Stern et al.'s (2014) systematic review of environmental education best practices. There appears to be overlap between EE and CS learning outcomes, but their research focusing on best practices is unique and could provide more theoretical legitimacy to those who are still skeptical of the accuracy of citizen science data collection.

Another interesting area to pursue might be the long-term implications of this experience. Environmental education as a field does a better job evaluating longer-term outcomes than the newer field of CS, evidenced in a whole area of longitudinal and reflective studies (Farmer et al., 2007; Knapp, 2000; Knapp & Benton, 2006; Liddicoat & Krasny, 2013; Olsson et al., 2022; Rioux & Pasquier, 2012; Schneller, 2008; Tal & Morag, 2013). It would be interesting to see how CS outcomes change if students participate in this over multiple camp seasons, and if the changes in science knowledge are translated back into the classroom –

potentially comparing scores on our evaluations to classroom scores or grades. It is our hope that these informal learning experiences do translate, but future research could address that directly.

Conclusion

The success of this work illustrates the potential of citizen science and environmental education to make a real impact on youth Interest, Knowledge, and Stewardship as it pertains to water quality and watershed health. Through these outcomes, we can arrive at better design and implementation to improve the impact of these programs.

Though citizen science began as a data collection tool for biologists, the power of it as an educational platform is exciting, especially for youth. While it certainly belongs in classrooms as a supplement to formal STEM education, summer camps and other nonformal learning environments should consider implementing citizen science programs to improve a variety of learning outcomes in a fun, novel way that is not associated with classroom learning. By providing these alternative educational experiences, we can hope to shape the next round of environmental leaders, or at least citizens with stronger environmental values.

Focusing on the experiences and outcomes of youth is critical for the continued success of citizen science. Understanding this can inform excellent program design and implementation to achieve not just individual learning outcomes, but movement towards larger social-ecological outcomes.

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Appendix A:

Pre-Survey and Post-Survey

Engaging in Citizen Science in the
West Fork River Watershed — Participant Survey

Survey conducted by:
Dr. Dave Smaldone
Recreation, Parks & Tourism Resources Program
Division of Forestry & Natural Resources
West Virginia University
David.Smaldone@mail.wvu.edu

Survey Directions:

Thank you for taking the time to complete this survey. The purpose of this survey is to understand your thoughts about the Engaging in Citizen Science project you will participate in at Jackson's Mill. This survey should only take about 10-15 minutes. Please read the instructions for each question and answer to the best of your ability. You can skip any question you want or stop at any time.

First, a few questions about you.

What is Today's Date? (write in month, day, & year)

____

So that your answers on this survey can be matched to responses you provide later, please ***create an ID number.***

Your ID number is the **two digits** that represent **your birth month**, the **two digits** that represent **your birthday**, and the **initials of your first, middle, and last name**. *So if your birthday is March 5 (03/05), and your name is Daniel John Smith, then your ID number would be 0305djs.*

Please enter your ID number here: _______________________________________

1. What is your gender? *(check one)*
   □ Male □ Female □ Other □ Prefer not to say

2. What is your age? *(please write in number)* ________

3. What grade are you going into this fall? *(check one)*
   □ Grade 6 □ Grade 7 □ Grade 8 □ Grade 9
   □ Grade 10 □ Grade 11 □ Grade 12

4. What race are you? *(check one or more)*
   □ White/Caucasian
   □ Black/African American
   □ Hispanic or Latino
   □ Asian
   □ American/Native Indian
   □ Pacific Islander
   □ Other
   □ Prefer not to say

5. What state do you live in?
   □ West Virginia □ Other state *(write in state name):*
   ____

6. Have you been to 4-H camp at Jackson's Mill before?
   □ Yes □ No

7. How many times have you been to 4-H camp at Jackson's Mill? *(write in number)*
   ____

8. Have you interacted with the West Fork River or Freemans Creek (local rivers at Jackson's Mill) before?
   □ Yes □ No

9. Before you started participating in this water quality monitoring project had you ever heard the term "citizen science"? *(check one)*
   □ Yes □ No

10. What does “citizen science” mean to you, or what do you think it might mean?

____

____

11. Have you ever participated in a citizen science project before? *(check one)*
□ Yes □ No
7a. ***If yes,*** please briefly describe the project and what you did while participating.

____
____

____
____

Now we’d like to ask some questions about water and water quality.

12. Ultimately, where does water usually end up after it enters a storm drain on a street? *(check one response below)*
□ Wastewater treatment plant
□ A local body of water
□ Into the ground
□ Don't know

13. Please list some specific types of information or data you think scientists should collect to measure or evaluate water quality in creeks or rivers. Then briefly describe what that specific information or data could tell us.

List data to collect/measure	*Why collect this data? What would this data tell us?*

14. Which of these is a type of pollution that hurts creeks here in the West Fork River Watershed (the local watershed)? *(for each item, place a check in the box that you think is correct)*

	No	Yes	Not sure
Fertilizer running off farm fields into the creek.			
Acid mine drainage pollutants caused by abandoned mines.			
Raw sewage from household pipes.			
Illegal dumping of trash into the creek.			

15. Please list one or more things ***YOU can do right now*** to help improve the water quality of local creeks here at Jackson's Mill, or near your home. *(briefly list as many things you can think of)*

____

____

____

Next we'd like to know what you think about science and creeks.

16. Please indicate how much you **DISAGREE** or **AGREE** with each of the following statements by **circling the number** in the appropriate column. Please respond as you really feel, rather than how you think "most people" feel. There are no right or wrong answers.

	Strongly Disagree	Disagree	Neither agree nor disagree	Agree	Strongly Agree
a. I enjoy learning science.	1	2	3	4	5
b. I want to understand how things in the environment or nature work.	1	2	3	4	5
c. I think science is interesting.	1	2	3	4	5
d. Learning science helps me understand about the environment or nature.	1	2	3	4	5
e. One day I would like a job that involves using science.	1	2	3	4	5
f. Knowledge of science will help me conserve the environment or nature.	1	2	3	4	5
g. I am familiar with how scientists use data to study water quality.	1	2	3	4	5
h. I can collect data that is valuable to scientists studying water quality.	1	2	3	4	5
i. Citizen scientists can contribute to science.	1	2	3	4	5
j. I am confident in my ability to contribute to scientific projects or research.	1	2	3	4	5

k. I can contribute to a citizen science project.	1	2	3	4	5
l. I am aware that my actions can impact water quality and the environment.	1	2	3	4	5
m. I am capable of making a positive impact on local streams and waterways.	1	2	3	4	5
n. I care about creeks.	1	2	3	4	5

17. This question is asking about your skills related to doing science. Please indicate how much you **DISAGREE** or **AGREE** with each of the following statements by **circling the number** in the appropriate column. Please answer in regard to what you think ***your skills are right now***.

	Strongly Disagree	Disagree	Neither agree nor disagree	Agree	Strongly Agree
a. I can ask a question that can be answered by collecting scientific data.	1	2	3	4	5
b. I can correctly write down or record scientific data.	1	2	3	4	5
c. I can collect scientific data following a step-by-step, standardized method.	1	2	3	4	5
d. I can use existing scientific data to answer a scientific research question.	1	2	3	4	5
e. I can analyze scientific data to figure out what it means, or what the results are.	1	2	3	4	5
f. I can communicate (present or talk about) scientific project results to others.	1	2	3	4	5

18. For each statement below, **first circle a number** in one of the columns under *"I know how to..."* that you agree with most, and **then place a check** in one column under "*Within the next year, I plan to...*".

	I know how to…					***Within the next year, I plan to…***		
	Strongly Disagree	Disagree	Neither agree nor disagree	Agree	Strongly Agree	No	Yes	Not sure
a. Help clean up or take care of a local stream, river, or lake.	1	2	3	4	5			
b. Participate in an environmental restoration activity (such as planting native trees or removing invasive plants).	1	2	3	4	5			
c. Talk to others about ways they can protect a local creek or lake.	1	2	3	4	5			

Thank you for answering these questions!

Engaging in Citizen Science in the
West Fork River Watershed — Participant Survey

Survey conducted by:
Dr. Dave Smaldone
Recreation, Parks & Tourism Resources Program
Division of Forestry & Natural Resources
West Virginia University
David.Smaldone@mail.wvu.edu

Survey Directions:

Thank you for taking the time to complete this survey. The purpose of this survey is to understand your thoughts after participating in the Engaging in Citizen Science project here at Jackson's Mill. This survey should only take about 10-15 minutes. Please read the instructions for each question and answer to the best of your ability. You can skip any question you want or stop at any time.

First, a few questions about you.

What is Today's Date? (write in month, day, & year)

____

So that your answers on this survey can be matched to responses you provided earlier, please ***create an ID number.***

Your ID number is the **two digits** that represent **your birth month**, the **two digits** that represent **your birthday**, and the **initials of your first, middle, and last name**. *So if your birthday is March 5 (03/05), and your name is Daniel John Smith, then your ID number would be 0305djs.*

Please enter your ID number here: ____

1. What is your age? *(please write in number)* ________

2. What does "citizen science" mean to you, or what do you think it might mean?

    ____

    ____

Now we'd like to ask some questions about water and water quality.

3. Ultimately, where does water usually end up after it enters a storm drain on a street? *(check one response below)*

- ☐ Wastewater treatment plant
- ☐ A local body of water
- ☐ Into the ground
- ☐ Don't know

4. Please list some specific types of information or data you think scientists should collect to measure or evaluate water quality in creeks or rivers. Then briefly describe what that specific information or data could tell us.

List data to collect/measure	*Why collect this data? What would this data tell us?*

5. Which of these is a type of pollution that hurts creeks here in the West Fork River watershed? *(for each item, place a check in the box that you think is the correct answer)*

	No	Yes	Not sure
Fertilizer running off farm fields into the creek.			
Acid mine drainage pollutants caused by abandoned mines.			
Raw sewage from household pipes.			
Illegal dumping of trash into the creek.			

6. Please list one or more things ***YOU can do right now*** to help improve the water quality of local creeks here at Jackson's Mill, or near your home. *(briefly list as many things you can think of)*

____
____

____
____

____
____

Next we'd like to know what you think about science and creeks.

7. Please indicate how much you **DISAGREE** or **AGREE** with each of the following statements by **circling the number** in the appropriate column. Please respond as you really feel, rather than how you think "most people" feel. There are no right or wrong answers.

	Strongly Disagree	Disagree	Neither agree nor disagree	Agree	Strongly Agree
a. I enjoy learning science.	1	2	3	4	5
b. I want to understand how things in the environment or nature work.	1	2	3	4	5
c. I think science is interesting.	1	2	3	4	5
d. Learning science helps me understand about the environment or nature.	1	2	3	4	5
e. One day I would like a job that involves using science.	1	2	3	4	5
f. Knowledge of science will help me conserve the environment or nature.	1	2	3	4	5
g. I am familiar with how scientists use data to study water quality.	1	2	3	4	5
h. I can collect data that is valuable to scientists studying water quality.	1	2	3	4	5
i. Citizen scientists can contribute to science.	1	2	3	4	5
j. I am confident in my ability to contribute to scientific projects or research.	1	2	3	4	5
k. I can contribute to a citizen science project.	1	2	3	4	5
	Strongly Disagree	Disagree	Neither agree nor disagree	Agree	Strongly Agree
l. I am aware that my actions can impact water quality and the environment.	1	2	3	4	5

m. I am capable of making a positive impact on local streams and waterways.	1	2	3	4	5
n. I care about creeks.	1	2	3	4	5

8. This question is asking about your skills related to doing science. Please indicate how much you **DISAGREE** or **AGREE** with each of the following statements by **circling the number** in the appropriate column. Please answer in regard to what you think ***your skills are right now***.

	Strongly Disagree	Disagree	Neither agree nor disagree	Agree	Strongly Agree
a. I can ask a question that can be answered by collecting scientific data.	1	2	3	4	5
b. I can correctly write down or record scientific data.	1	2	3	4	5
c. I can collect scientific data following a step-by-step, standardized method.	1	2	3	4	5
d. I can use existing scientific data to answer a scientific research question.	1	2	3	4	5
e. I can analyze scientific data to figure out what it means, or what the results are.	1	2	3	4	5
f. I can communicate (present or talk about) scientific project results to others.	1	2	3	4	5

9. For each statement below, **first circle a number** in one of the columns under *"I know how to..."* that you agree with most, and **then place a check** in one column under "*Within the next year, I plan to...*".

	I know how to…					***Within the next year, I plan to…***		
	Strongly Disagree	Disagree	Neither agree nor disagree	Agree	Strongly Agree	No	Yes	Not sure
a. Help clean up or take care of a local stream, river, or lake.	1	2	3	4	5			
b. Participate in an environmental restoration activity (such as planting native trees or	1	2	3	4	5			

removing invasive plants).								
c. Talk to others about ways they can protect a local creek or lake.	1	2	3	4	5			

10. Please indicate how much you **DISAGREE** or **AGREE** with each of the following statements by **circling the number** in the appropriate column.

Please begin each statement below with: **"*Participating in this project has…*"**	Strongly Disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree
Improved my understanding of how scientists gather and use data to monitor water quality.	1	2	3	4	5
Contributed to the scientific knowledge about the West Fork River (& other local creeks).	1	2	3	4	5
Increased my appreciation for creeks.	1	2	3	4	5
Increased my connection to creeks.	1	2	3	4	5
Made it more likely that I will participate in other projects related to improving the environment.	1	2	3	4	5

11. Please indicate how much you **DISAGREE** or **AGREE** with each of the following statements by **circling the number** in the appropriate column.

Please begin each statement below with: *"**Since my participation in the West Fork River Citizen Science project…**"*	Strongly Disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree
I have talked about the project with others (who were not involved in the project).	1	2	3	4	5
I have made changes in my daily life related to improving water quality based on what I've learned from the project.	1	2	3	4	5
I have used social media to communicate or share with others about the project.	1	2	3	4	5
I have searched for more information about water quality in general.	1	2	3	4	5
I have searched for more information about how I can improve water quality near where I live.	1	2	3	4	5

12. What is the **most important thing you have learned** so far while participating in the West Fork River Citizen Science Project? *(please write in a brief answer below)*

Thank you for answering these questions!