Elevating the Civic Science Literacy of American Adults; Assessing a Renewed Citizen Science Paradigm Integrating Nonformal Outdoor Adult Education and Enhanced Experiential Learning

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Elevating the Civic Science Literacy of American Adults: Assessing a Renewed Citizen Science Paradigm Integrating Nonformal Outdoor Adult Education and Enhanced Experiential Learning

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My Mother and Father for all their love and support;
My beautiful family - Alison, Shiloh, Tesse Belle, Fidget, and Beauregard;
My friend, Albert M Forney, and family, Buster,
who were lost during this arduous journey.
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Elevating the Civic Science Literacy of American Adults:  
Assessing a Renewed Citizen Science Paradigm Integrating Nonformal Outdoor Adult  
Education and Experiential Learning  

DAVID P. CRONIN  

ABSTRACT  

America’s adult populace has failed to keep pace with the rapid inundation of science-centric advancements affecting nearly every facet of personal and public life. With deficiencies in areas of science knowledge, America’s adult populace is characterized as civic science illiterate. This research constructed and employed the renewed citizen science paradigm, incorporating nonformal outdoor adult education and enhanced experiential learning while maintaining the basic tenet of citizen science, towards elevating the civic science literacy of adults who volunteered to conduct scientific research towards answering important research questions posed by a science research agency. With 67 volunteers, 23 adults were purposively selected on the basis of their complete participation throughout the program. Data were collected through a concurrent mixed methods design, and both quantitatively, self-report surveys (n=23), and qualitatively, mixed method interviews (n=10), analyzed. The results demonstrate that the renewed citizen science paradigm statistically significantly elevated the science vocabulary knowledge (p<0.001) and science process understanding (p<0.001) of participating adults; while collecting over 30,000 pieces of scientific data in conducting research for an outside agency. Additionally, the research communicates how marked elevations in civic science literacy catalyzed volunteers to participate and assert their new civic science literacy in personal, social, and political forums, having taken ownership of
the scientific results and acting as advocates for its conclusions. As our globally expanding society becomes increasingly embedded in science and technology, there is an important need to continue elevating the civic science literacy of the adult populace.
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CHAPTER I
INTRODUCTION

Advancement in the scientific community’s knowledge and understanding of the sciences is occurring at an unprecedented rate, both in theory and in practice. Natural, physical, and analytical science topics have become a recurrent theme in nearly every facet of public life and partisan politics; facets that touch each and every American in some manner on a daily basis (i.e. the energy crises and rising costs of petroleum products, the health care crisis and rising costs of prescription drugs, climate change and the rising costs of agriculture-based commodities, etc.). As our globally expanding society becomes increasingly embedded in science and technology that both affects individuals and contributes to the overall public welfare of American society, there has arisen an important need to improve the civic science literacy of the adult populace. Such educational advancement is prompted towards both the betterment of the adult citizen’s personal, familial, and communal lives, as well as improving their capability to propose, vote on, and execute science-centric policy. To effectively act on all levels of science, American citizens must have a general foundation and understanding of scientific vocabulary and the process dynamics that envelop scientific phenomena. Today’s American adult is grossly deficient in these domains, both constituting a lack of civic
science literacy and illustrating a remnant of our country’s past and continuing convictions regarding the interrelationships of science, education, and society.

In 1983, educational researcher Paul Hurd (as cited in NCEE, 1983) revealed concern regarding the growing disconnect of Americans and science. According to Hurd, "We are raising a new generation of Americans that is scientifically and technologically illiterate.” This sentiment was shared by former National Science Foundation (NSF) director John Slaughter (as cited in NCEE, 1983) who uncovered, "a growing chasm between a small scientific and technological elite and a citizenry ill-informed, indeed uninformed, on issues with a science component.” A quarter of a century later, empirical evidence continues to unveil that the state of scientific knowledge among American adults is grossly deficient. A 2007 poll by Jon Miller (as cited in Brainard, 2008) of Michigan State University revealed, “only 25% of American adults are considered scientifically literate” (p. A9). Miller suggests that the only way to improve civic science literacy is to begin by improving the public’s understanding of scientific vocabulary and then building their repertoire of skills towards understanding scientific processes and the impact that science has on their lives (Miller, 1998; Miller, 1993).

The ubiquitous problem of civic science illiteracy becomes compounded when addressed as a social phenomenon. In his 1975 discussion on science advancement, Benjamin Shen (1975) stated, “It has been estimated that, in the United States, a little over half of the legislative bills in Congress now have a scientific or technological basis” (p. 48). Without the ability to understand the basic scientific vocabulary and process dynamics embedded in policy, American adults, including policymakers themselves, have been relegated to the mainstream media for science education. Unfortunately, even
the most highly respected media outlets have become financially and politically motivated in their reporting. “The concept that news should be objective is increasingly treated within the profession as old-fashioned and outdated,” states Pulitzer Prize-winning journalist Alex S. Jones (2009, p. 82). Scientific content is becoming all too often misleading or completely false, and is commonly generated by special interests for self-promotion. “A genuinely informed citizenry,” Jones hypothesizes in the wake of the changing face of the media, “is replaced with an anarchy of half-truths, misinformation, and propaganda” (p. 32).

1.1 Research Problem

Any member of the general public who chooses to seriously engage in, contest, or personally implement any issue with scientific dimensions must learn the science related to the issue(s). More importantly, with the salient role of science in American’s personal lives and livelihood, scientific knowledge must go beyond basic facts and trivia and encapsulate a full literacy of science and scientific processes. “The rhetoric,” states Jenkins (1999), “is that citizens need to be scientifically literate in order to be able to contribute to decision-making about issues that have a scientific dimension, whether these issues be personal (e.g. relating to medicine or diet) or more broadly political (e.g. relating to nuclear power, ozone depletion or DNA technologies)” (p. 703). “The problem, of course,” reviews Sarewitz (2003), “is that few people (perhaps none) have the breadth of understanding to even begin to provide a valid account of what will happen as a result of a five percent decrease or increase in, say, chemistry, or a 100 percent increase in cancer research” (p. 14). In a less subtle argument, American adults lack the
necessary knowledge needed to understand science, scientific processes, and the ramifications of supporting and executing science-based policy.

The average American’s understanding of science is less than desirable (Mervis, 2007; Cetron & Gayle, 1991; Ruvinsky, 2007; Jenkins, 1997). The roots of this phenomenon have been researched in depth throughout the past two decades; only to conclude that today’s adult’s lack of science literacy is attributable to a lack of enthusiasm, motivation, and/or general interest in science during their matriculation thru grade school (Freedman, 1997; National Research Council, 1996; Cavallo & Laubach, 2001; Stake & Mares, 2001; Jones, Howe & Rua, 2000; Meyer, 1998; Hornung, 1987). When students, particularly those in middle school, lose interest in the sciences, the result is often a total disassociation from the domain - throughout high school and beyond - as students continue to find the subject matter boring, irrelevant, and most importantly, difficult (Handler & Duncan, 2006). According to Cavallo and Laubach (2001),

These issues have been so pervasive that the National Science Teachers Association, American Association for the Advancement of Science, American Chemical Society, and National Committee of Science Education Standards and Assessments have each developed initiatives specifically directed towards promoting scientific literacy among all students and encouraging more students to pursue science-related careers” (p. 1030).

But science has not always been a requisite area of study for American students, particularly during the period of formal education experienced by today’s adult. Nearly all adults within our nation’s population were K-12 students prior to state and/or federally mandated standards in the natural and physical sciences. For those who did enroll in science coursework, the traditional science education foundation was littered with inadequacies that led to poorly constructed and executed science courses (Aikenhead, 1994). While previous research has been important in catalyzing efforts to develop a
remedy for an anticipated shortage of American scientists, an estimated one million by the year 2010 (Cetron & Gayle, 1991), it continues to fail to address the adult learner who has matured into a more scientifically aware twenty-first century citizen seeking scientific literacy. Among the overarching reasons for this omission is the belief that adults seeking science literacy are already capable of being served by the nation’s formal institutions of higher education.

According to Jeffrey Brainard (2008, p. A9), “The reputation of science as boring and only for nerds is beginning to change.” Humans, unlike the mindless creatures of paleontological studies, have an insatiable desire to learn on a consistent basis. Even within the most prevalent knowledge transmission mediums of today - television, magazines, newsprint, and the Internet – humans electively seek and are invigorated by the available knowledge and educational opportunities that surround them. With both time constraints and economic solidarity being of prime importance for many American families today, many adults find that formal education is not a feasible option. But the reasons for the avoidance of formal education forums go well beyond time and money. The primary problems are well synthesized by Afamia Elnaka (2002) who states that the communication of science content “does not always take into account factors such as access to technology, historical attitudes and claims to resources, economic level, and social and cultural differences” (p. 2). In addition, many adults are self-conscious; they report feeling “intimidated and uncomfortable in formal education forums surrounded by students, and in some cases professors, young enough to be their own children,” states adjunct professor Alison Yasick (personal communication, March 2, 2009). In a similar breath, former U.S. Olympian Dee Miller reflected on returning to college after eight
years of international competition. “As an older college student,” states Miller (as cited in Technology & Development, 2001), “I was thrown back into a traditional learning environment that didn’t have a lot of real-world application” (p. 66). For those adults who matriculated through formal higher education in their past, personal disenfranchisement with these systems impede their return for innumerable reasons. One overarching hypothesis presented by Walter and Marks (1981) state, “For many, past disappointments and frustrations have resulted in disinterest in and possible withdrawal from all formal learning activities” (p. 5).

With formal education being a limiting aspect for many American adults, the adult population has sought to find science education, adventure, recreation, personal meaning, and solace in a cost efficient and existentially comfortable manner - in the “great outdoors.” This alternative classroom selection is not surprising given the omnipresence of public policy and media coverage regarding environmental issues coupled with the vast array of nonformal and informal education opportunities available throughout the United States. One of the more popular forums that have arisen in prominence is citizen science programming.

As a catch phrase for any organized scientific endeavor that utilizes volunteers, many of whom are adults with no scientific training, citizen science programs are procuring volunteers on an unprecedented level. For over a century, scientists within academia and other professional, scientific organizations have solicited the general public to collect valuable research data that would otherwise be spatially, temporally, and/or financially prohibitive to secure. Citizen science, state Cooper, Dickinson, Phillips, and Bonney (2007), “engages a dispersed network of volunteers to assist in professional research
using methodologies that have been developed by or in collaboration with professional researchers…[and] The public plays a role in data collection across broad geographic regions (and often, over long periods of time), usually to address questions raised by researchers” (p. 11). To use volunteers from the general public not only serves as a tremendous pool of human resources in the acquisition of scientific data, but the apportionment of volunteers allows researchers to address ambitious problems without spatial or temporal boundaries.

The most salient question today is how can civic science literacy be made a primary goal of citizen science programming without disrupting their value as data collection tools? Towards answering this question, this research solicited a long-standing, institutionally sponsored citizen science program and asked them to enable the development and implementation of nonformal outdoor adult education and enhanced experiential learning for their adult participants throughout the program’s execution. Through self-report surveys (n=15) and mixed-method interviews (n=10), this research evaluated both Handler and Duncan’s (2006) meta-analysis concluding “that inquiry-based learning [experiential learning] focuses on scientific process at the expense of content learning” (p. 10), and how content learning expanding the epistemological foundation of civic science literacy can be elevated through a renewed citizen science paradigm – a paradigm built on the mergence of nonformal outdoor adult education and enhanced experiential learning in citizen science programming.

1.2 **Statement of the Problem**

The fundamental problem facing American adults is a lack of requisite levels of civic science literacy and the proper forum for elevating their civic science literacy. Citizen
science programming is in an ideal position to serve both the American populace and the scientific community towards efficacy in many domains. In a recent article on citizen science, Cohn (2008) expands on the component of volunteers in these endeavors, calling them “field associates in scientific studies” (p. 193). Within the many defining roles of the citizen science volunteer is making and recording observations, making quantitative measurements, and using computational and thematic software for data collection and distribution. For their part, citizen science volunteers have the pleasure of knowing that they have contributed to research that would otherwise be unfeasible, and, hopefully, walked away with some knowledge of science. But the average citizen chooses to volunteer for a multitude of reasons that extends beyond being philanthropic with one’s time; reasons that often begin with science education. Unfortunately, this most valuable of the volunteer’s goal in participation is rarely realized throughout the course of participation; only emerging as fragmented knowledge gained through self-guided, informal education.

1.3 Filling a Gap

While continuing professional education and lifelong learning have become the mainstay for science literacy development in professional realms (predominantly in the domain of occupational health and safety), there are limited forums for American adults seeking civic science literacy in the natural and physical science domains for personal and social purpose. With documented barriers preventing formal education as a forum for improving civic science literacy for many American adults, an unprecedented number of American adults are participating in nonformal and informal education programs centered amid natural science topics. Given its spatially and temporally expansive
relevance, citizen science programming has become one of the more popular forums for science education but continues to circumvent science education and civic science literacy development in lieu of generating research data and publishable results. As both an educator and researcher in the natural sciences, this work acknowledges the value and importance of citizen science programs and their volunteers in researching numerous scientific phenomena and advancing the greater scientific community’s knowledge of these phenomena. However, this work also acknowledges that citizen science programs have the greatest opportunity to reach the American adult population most in need of civic science literacy.

1.4 **Purpose of the Study: Research Hypotheses**

The purpose of this study was to demonstrate that a renewed citizen science paradigm, incorporating nonformal outdoor adult education and enhanced experiential learning through the framework of James Coleman (1976), can improve the civic science literacy of adult volunteers while maintaining the central tenets of citizen science programming. Questions that guided this study are:

1. Can nonformal outdoor adult education incorporating experiential learning in a renewed citizen science paradigm improve the civic science literacy of adult participants?

2. To what extent can nonformal outdoor adult education incorporating experiential learning in a renewed citizen science paradigm that addresses and advances the civic science literacy of adult participants elevate the participation and assertion of volunteers in social forums and within a scientifically evolving democracy?
1.5 Significance of the Study

1.5.1 Stop Acknowledging the Problem and Start Solving It

America’s adult citizenry has failed to keep pace with scientific knowledge and systematic advancements in science. These failures disable the adult citizenry from facilitating the rapid inundation of science-based content and phenomenon in their daily lives, renders them uninformed as participants in democratic processes involving science-based policy and issues, and deems them incompetent to execute science with any level of process-understanding; even when such decisions directly affect their person, their family, and their community. While hundreds of pieces of previous research attempt to identify and explain the resounding factors that evolved within an educational system of days past that stigmatized and disenfranchised students from the sciences, this research largely ignores the source of these failings and introduces an innovative methodology for addressing a lack of civic science literacy in the here and now.

1.5.2 Elevating Civic Science Literacy While Meeting Other Organizational Goals

Over 200 scientific research projects utilizing citizen scientists are being performed across North America today, although thousands more may exist on a local level. The National Science Foundation (NSF) is funding approximately twelve of these programs, and, according to David Ucko, deputy director of the NSF’s division for learning (as cited in Cohn, 2008), “Our objective is to increase public awareness of and participation in science. Actually, we are more interested in the educational values than the research results” (p. 193). This research demonstrated that a renewed citizen science paradigm, through the addition of nonformal outdoor adult education and enhanced experiential learning in citizen science programs, can achieve the goals of both research results
through data collection and improving the civic science literacy of its participants. In addition, the renewed citizen science paradigm added to the overall professional practice of adult education by demonstrating how adult education can diverged from its roots towards more cross-disciplined, personally rewarding educational experiences serving the greater good of institutional research.

1.5.3 Solving the NSF Problem: Meet Both Research Needs and Educational Goals

The idea of science and adult education merging in citizen science programming is not a novel concept. Previous research, such as that performed by Cooper et al. (2007), reveals one such conceptualization in which “Participants not only collect data on ecosystem elements (e.g. bird populations) but also manipulate habitat to examine the effect on the ecosystem or become advocates seeking to modify human behavior (e.g., keeping cats indoors)” (p. 11). This manifestation of science literacy through informal experiential learning suggests that citizen science programs evolve to include two distinct series of measurable outcomes, the first addressing the central scientific work being performed by citizen science volunteers (e.g. collect data on ecosystem elements) and the second to address more personal and more socially-oriented outcomes evolving from researcher suggestions (e.g. manipulate habitat, and becoming advocates seeking to modify human behavior). But volunteers need to be able to address more personal and socially-oriented science autonomously. Whereas there is little doubt that civic science literacy can be a resounding result of citizen science programs, there continues to be a failure of creative suggestions as to how the citizen science volunteer is to acquire civic science literacy through their involvement in institutionally-based scientific research. A review of the literature identifies two important components that are absent from citizen
science for building civic science literacy: a) a specified goal to improve the participating 
volunteer’s scientific vocabulary and understanding of scientific processes through adult-
oriented educational programs; and, b) nonformal education - an “organized, intentional 
and explicit effort to promote learning to enhance the quality of life through non-school 
settings,” as defined by Joe Heimlich (1993, p. 2).

1.5.4 American Adults and the Scientific Community: Create a Working Relationship

Scientists teaching science is not a novel idea by any stretch of the imagination. 
Museums, zoos, parks, expositions, and other out-of-classroom science-based forums 
have been successfully serving both the scientific community and the greater populace of 
those seeking education and entertainment for centuries. For nonformal education to 
become an integral part of the renewed citizen science paradigm, brochures and websites 
must be replaced with an instructor who is “more present-time focused, responsive to 
292). Without a structured classroom hierarchy, these complexities, among others, 
corner those offering nonformal education to consistently act and react, both to moment-
by-moment in-class dynamics and general societal interests and concerns. Both of these 
caveats are of prime importance if the civic science literacy of citizen science volunteers 
is to be markedly improved, and they also help to explain the lack of nonformal outdoor 
adult education in traditional citizen science programs. The relationship of citizen 
science sponsoring institutions and the citizen science volunteer within the renewed 
citizen science paradigm becomes very simple; recognize that while “institutions make 
things possible,” states Zahariadis (2007, p. 84), “people make things happen.”
1.5.5 Pyramid-Schemed Docent Led Education

As a field of professional practice, academia has generally perpetuated a disconnect between institutional and general populace interests; ignoring the professional and intellectual contributions that our nation’s citizenry (e.g. participation without remuneration, past professional and personal experiences in thousands of domains, the level of localized expertise they can bring to a project, their maturity and willingness to work with integrity towards meeting larger research scientific goals that affect our nation, etc.) can make in advancing scientific knowledge and assisting institutions. For decades, citizen science programming – whether clearly defined or not – has been innovative in catalyzing the emergence of America’s adult citizens and academia towards addressing scientific research goals.

American citizens are ready and able to be challenged towards meeting larger research goals - goals that are often overlooked or approached frivolously due to budgetary constraints. For many older adults, as discussed by Freedman (as cited in Eisen, 2005, p. 22), there is “a growing movement of retired professionals who are…not content to embrace the ‘golden years’ notion of leisure, recreation, and disengagement…[rather, they seek] greater meaning, stimulation, and the chance to make a difference” (p. 22). With 76 million baby-boomers having met or approaching retirement with an uneasiness towards filling their time outside of their standardized routines amid fiscal uncertainty, the time is now for academic and professional institutions to recognize the value of both working adults and retirees willing to provide their time without financial remuneration to help address emerging scientific issues, learn the science related to the issues, and become ambassadors for the science within the greater populace. This research, both in theory and practice, fills a void in the literature with the renewed citizen science paradigm and its adaptability to accommodate
a docent framework enabling more traditional, expansive citizen science program research to be performed within the constructs of the renewed citizen science paradigm. Having unveiled that many adult volunteers in the renewed citizen science paradigm have the motivation and personal desire to take on larger roles and share their acquired civic science literacy towards educating others on the scientific content of the program, a pyramid docent scheme embracing the traditions of the docent council (Grenier, 2009) can evolve for the purpose of networking spatially and temporally controlled renewed citizen science programming with the professional researcher(s) and research organization(s) in a time and cost efficient manner.
CHAPTER II
LITERATURE REVIEW

Towards establishing a working foundation for this research, hundreds of modern and archival works were drawn from over a dozen academic and professional domains. The literature isolated both the fundamental platform for expounding upon the central topic and isolated gaps within the literature base worthy of discussion.

The literature review necessarily begins with an exploration of civic science literacy and its unique identity within the greater realm of science literacy. The review defines and isolates the modern importance of civic science literacy, as well as answering the question: why is it important to be civic science literate? This review is followed by the academically constructed and derived “nonformal outdoor adult education,” an appellation providing specificity and utility within the context of this research. The appellation begins by breaking down both outdoor education and adult education before contriving their mergence into an appropriate andragogical construct for this work.

In addition to the preceding constructs, the literature review concludes with an expansive discussion of experiential learning and citizen science – establishing both the best practice and the best forum for addressing the research problem. As one of the most ubiquitous and preeminent forms of knowledge transfer, the vastness of experiential
learning theory requires synthesis and precision in its epistemological role and best approach in establishing the boundaries of the theory in practice. Finally, with a working framework in hand, citizen science is reviewed as both an institutional practice and an innovative forum for elevating the civic science literacy of American adults.

2.1 **Science Literacy and Society**

Throughout the late 1960s and into the 1970s, there was resurgence in public enthusiasm towards learning science, a renaissance of inquiry unparalleled since the days of the exposition and lyceum. As Americans delved deeper into the Cold War and the emerging scientifically based public policy and legislation that accompanied advancement, national organizations such as the American Association for the Advancement of Science (AAAS) and the National Science Foundation’s (NSF) Office of the Public Understanding of Science looked for feasible ways to satisfy public demand (Shen, 1975). The immediate problem facing the general public’s acquisition of scientific literacy was quite simple - the scientific community did not want to participate. In fact, many scientists were adamantly opposed to creating a scientifically literate citizenry, pointing out that science is an elitist calling. The argument contends that the average citizen does not have the skills or basic intelligence to understand or execute science (Levitt, 1999) and assisting them would be an irresponsible use of such valuable knowledge resources. Such an absurd notion as developing scientific literacy for the general public as suggested, state Roth and Lee (2004), “poses a threat to the hegemony of scientific expertise in everyday affairs” (p. 265).

The inexorable disconnect between the general public and the scientific community reached its nexus when general funding for scientific research began to wane. Exposing
the unwritten agreement to advance scientific literacy, writes Benjamin Shen (1975), “once again the initial motivation concerned research funding: government funds were becoming scarce, and a better acquaintance with science on the part of the public was thought to be a way to reverse the trend” (p. 45). Immediately, a general willingness from the scientific community-at-large to share science in a manner that was understandable, and meaningful for the average citizen emerged. However, as Jenkins (1999) recalls, “science itself emerges not as coherent, objective, and unproblematic knowledge, but as uncertain, contentious and often unable to answer many important questions with the required degree of confidence” (p. 704).

Currently, the average American’s understanding of science is less than desirable (Mervis, 2007; Cetron & Gayle, 1991; Ruvinsky, 2007; Jenkins, 1999). The causes have been researched and hypothesized in depth throughout the last decade; often attributing today’s adult’s lack of science literacy to a lack of enthusiasm, motivation, and/or general interest in science during matriculation thru grade school (Freedman, 1997; National Research Council, 1996; Cavallo & Laubach, 2001; Stake & Mares, 2001; Jones, Howe & Rua, 2000; Meyer, 1998; Hornung, 1987). While this research has been important in developing a remedy for a shortage of American scientists, an estimated one million by the year 2010 (Cetron & Gayle, 1991), it does not address the adult learner who has matured into a more scientifically complex twenty-first century citizen. This renewed enthusiasm, motivation, and attitude towards science among adults reflects the increasing role of science within American culture, as relayed to the public through the Internet, television programming, and other media outlets, particularly in the domains of environmental science, ecology, and the broader field of natural science.
Scientific literacy, as articulated by Shen (1975), is “an acquaintance with science [both basic and applied], technology, and medicine, popularized to various degrees, on the part of the general public and special sectors of the public through information in the mass media and education in and out of schools” (p. 45). Within American communities, scientific literacy is often equated with power; the power to find and use information at the exact moment one needs it (Roth & Lee, 2004). This power may be executed in families and personal circles, or used to address more widespread social and political issues.

Any member of the general public who chooses to seriously engage in, or contest, any social or political issue with scientific dimensions must, at some point, learn the science related to the issue(s). Scientific knowledge must go beyond basic facts and trivia and encapsulate a full literacy of science and scientific processes. In creating a democratic citizenry in the sciences, states Jenkins (1999), “the rhetoric is that citizens need to be scientifically literate in order to be able to contribute to decision-making about issues that have a scientific dimension, whether these issues be personal (e.g. relating to medicine or diet) or more broadly political (e.g. relating to nuclear power, ozone depletion or DNA technologies)” (p. 703). As such, scientific literacy need not only be valued as a tool towards democratic change; it is just as importantly a tool for personal development and social transformation.

The general public, those without a strong academic and/or working science background as is so often the case with science literacy, also includes policy makers, lobbyists, and politicians. According to Choi (2005), “News reports and case reports often play an important role in policy decisions, because decision makers, including those
in the general public, often do not have the time, ability, or expertise to access and synthesize the evidence from high-quality studies.” With scientific research constantly being published, including the estimated 17,000 biomedical books published each year, it is easy to understand, states Choi, “At some point, the average policymaker and even some scientists cannot understand the information.” One salient example is the number of policy makers who have fallen victim to the dihydrogen monoxide hoax created by three students at the University of California Santa Cruz in 1990.

Dihydrogen monoxide is one of several scientifically accepted terms for the chemical compound commonly known as water. But the word “monoxide,” often associated with carbon monoxide in the same negative light that nuclear power reactors are associated with nuclear bombs (as if they are one in the same), has provided a misleading and dangerous platform for decision makers relying on what they believe to be credible, scientifically sound knowledge. The most recent publicized examples include Jacqui Dean, a member of New Zealand parliament, who wrote a letter to Associate Health Minister Jim Anderton to ask for the Expert Advisory Committee on Drug’s opinion on banning dihydrogen monoxide after learning that the colorless, tasteless, odorless chemical compound is responsible for thousands of deaths each year (Gnad, 2007). Similarly in 2004, a full ban on the use of foam containers in Aliso Viejo, California was put on the city council agenda after learning that dihydrogen monoxide is used in their production (Associated Press, 2004).

While the dihydrogen monoxide hoax is not considered funny to those elected officials dedicated to protecting the public’s health, those who have been fooled by it provide a very real example of how a lack of science literacy and a unilateral reliance on
second hand knowledge can have a very real impact in policy circles; not to mention for the livelihood and activities of the general adult populace. Following extensive media coverage on the death of Rock Hudson in 1985, American’s became acutely aware of acquired immunodeficiency syndrome (AIDS). Shortly following Hudson’s death, a public panic consuming policy makers, politicians, and nearly every American ensued when during a nationally televised broadcast, Oprah Winfrey, relying on secondhand knowledge, hypothesized an AIDS pandemic and “told her audience that one in five heterosexuals would be dead of AIDS by the 1990s,” states Bethell (2005, p. 113).

Many believe that a lack of scientific literacy on the part of those relying on accurate accounting from the scientific community can be directly correlated to our nation’s lack of advancement in such ubiquitous science domains as cancer, global warming, invasive species, pesticides, stem cells, and AIDS (Bethell, 2005). But members of the media, most of whom lack science literacy themselves, are just as much to blame. According to Elnakat (2002), “the media…have become so inconsistent, thus making it harder for the public and policymakers to take science and its contributions seriously” (p. 2). Considering the bombardment of scientific knowledge the average citizen receives today, much of which falls victim to revisions and distortions as it passes through the hands of special interest groups and back into the mainstream media, it is not difficult to understand the average citizen’s overall lack of science literacy. This state of scientific knowledge in America is particularly disconcerting when members of the general citizenry truly feel that they have achieved some level of scientific literacy only to find out that what they have accepted as scientific truth emerges as fallacious or distorted science.
2.2 Science Literacy Typology

Scientific literacy can be demarcated into three broad categories: practical science literacy, cultural science literacy, and civic science literacy. While there is plenty of overlap between the three categories of scientific literacy, the objectives, content, format, audience, and mode of delivery provide a “sufficiently distinct” separation in delineating the three categories (Shen, 1975).

2.2.1 Practical Science Literacy

Practical science literacy is loosely defined as the public understanding of scientific knowledge to an extent in which the public can use such knowledge to solve everyday problems, particularly knowledge procured for the most visceral human requisition of survival. Concentrating heavily on basic science, and relaying subject-specific knowledge on nutrition, medicine, agriculture, and safety, public participation in practical science literacy is maximized through interpersonal knowledge transmission, familial and communal discourse, and personal experience. “In deciding how and when to act in practical matters that have a scientific dimension, states Jenkins (1999), “scientific knowledge is considered alongside this other, experiential and personal knowledge base” (p. 705). The importance of practical science literacy is so profound within human communities that, “the urgency of practical science literacy will in some cases justify its taking precedence over alphabetic literacy in developmental planning,” proclaims Shen (1975, p. 47). Without the ability to survive as both a member of the Homo sapien species and, taxonomically, the broader animal kingdom, all other possible knowledge becomes superfluous.
2.2.2 Cultural Science Literacy

Cultural science literacy serves as a method of general science-based knowledge acquisition in bridging a gap between two cultures, particularly two distinct professional or personal cultures (such as a lawyer reading about stem-cell research, a truck driver listening to a radio talk show on the human genome, or a poet watching a television program about shield volcanoes). Cultural science literacy, states Shen (1975), “is motivated by the desire to know something about science as a major human achievement” (p. 49). Magazines such as Scientific American, Nature, Smithsonian Magazine, Popular Science, and a wide-array of television programming on Discovery, Animal Planet, NatGeo T.V., and the Science Channel, serve to bridge the cultural gap by enabling the general public to become apprised of notable and ubiquitous science subjects, as deemed personally profitable, by primary media outlets. The media outlets serve a valuable role for the general citizenry, as discussed by Layton, Davey, and Jenkins (1993), by translating scientific systems and vocabulary into a more easily understood vernacular and communicable form; a form cogently antithetical to academic and professional science. Cultural science literacy is epitomized by informal education and the acquisition of cultural science literacy has little to no consequence in an individual’s daily life.

2.2.3 Civic Science Literacy

Civic science literacy separates itself from practical science literacy and cultural science literacy in that the primary objective is the development of a society forged with the ability to make important scientific decisions regarding one’s life and to engage and participate in democratic processes centered upon science content (Shen, 1975). Basic
and applied science topics are a recurrent theme in many facets of politics and public policy, and many of these facets touch each and every American in some manner (i.e. the energy crises and rising costs of petroleum, the health care crisis and rising costs of prescription drugs, the climate change crisis and rising costs of agricultural commodities, etc.). There is no escaping the fact that all manner of humanity has a reciprocating relationship with science. All humans must be aware of how their actions and decisions affect the scientific world, and how the scientific community and notions of collective good shapes human action. In his 1975 discussion on civic science literacy, Shen (1975) stated, “It has been estimated that, in the United States, a little over half of the legislative bills in Congress now have a scientific or technological basis” (p. 48). In the absence of any quantifiable data more than 30 years later, it would be tremendously modest to say that this estimate has not decreased. According to Elnakat (2002), “Little effort has been made to understand how the assessment of scientific and technical information interacts with decision and policymaking, basically, because there has not been much interaction to be studied” (p. 2).

Where civic science literacy separates itself from practical science literacy and cultural science literacy is in democratic processes, where a constitutional mandate constrains whom among Americans may participate. As such, civic science literacy has a quasi age-specific parameter defining the audience of civic science literacy as adults 18 years of age or older. While a younger audience is certainly raising clout within modern democratic processes, adults remain the vanguard of civic science literacy for personal, familial, and communal science decision making.
Among the three prevalent forms of scientific literacy, there is no doubt that civic science literacy is both in its infancy and the category that is the least pervasive among the general public (Miller, 1998). Among the most salient reasons for a lack of civic science literacy is that the general populace, regardless of background or experience, has little to no knowledge of scientific principles and vocabulary (Shen, 1975; Pool, 1991; Miller, 1998; Jenkins, 1999). A 2007 poll by Jon Miller of Michigan State University indicated that only 25% of American adults are considered scientifically literate” (Brainard, 2008). According to Miller (as cited in Brainard), “A passing score roughly equates to an ability to comprehend the weekly science section of The New York Times or the documentaries on the public-television show Nova” (p. A9). Miller suggests that the only way to improve civic science literacy is to begin by improving the public’s understanding of scientific vocabulary. Part of this endeavor includes omitting the use of “many acronyms and terms that,” state Elnakat (2002), “are not found in a typical dictionary” (p. 3). Once an individual’s scientific vocabulary is improved, one can begin building their repertoire of skills in understanding scientific processes and the impact that science has on their lives (Miller, 1998; Miller 1993). In brief, one can improve their civic science literacy regardless of age. But where do we begin?

According to Jeffrey Brainard (2008), “The reputation of science as boring and only for nerds is beginning to change” (p. A9). Topics such as environmentalism, alternative fuels, endangered species, global climate change, conservation, recycling, and many other topics affecting the outdoors and ecology, are now central themes in many casual conversations. “In recent times,” states Elnakat (2002), “there has been a shift of social goals reflecting concerns regarding environmental issues” (p. 1). These shifts have led to
an unprecedented number of legislative bills, along all levels of Federalism, introduced, supported, and/or contested by the average citizen because the results of such legislation affects the average citizen. This ongoing affinity of the general public for scientific knowledge in the natural and physical sciences makes these topics ideal as a starting ground for improving our adult populace’s civic science literacy - topics that have become the mainstay of outdoor adult education.

2.3 Nonformal Outdoor Adult Education: What’s in a Name?

2.3.1 Outdoor Education

Since the recognition of outdoor education as a discipline in the early half of the nineteenth century, numerous scholars and professionals alike have attempted to define exactly what is meant by “outdoor education.” By all standards, defining outdoor education should appear to be a simplistic task. Each word, on its own merit, is denotatively clear. However, outdoor education is not simply a compound locution, and has been defined in a number of ways (Priest, 1988; Neill, 2008). One of the reasons for the lack of agreement in defining the term is that outdoor education is a process with many attributes and dynamic components, both spatially and temporally. Just as “Nature, herself, is never static,” laments Hoffmaster (1950), the interpretive aspects of outdoor education vary across culture, philosophy, and geography” (p. 519).

Whereas one author may feel that outdoor education is simplistically and clearly definable as learning in the out-of-doors, authors such as Martin (1996) transcend traditional thinking to include “Images of cliffs as playgrounds or gymnasiums, images of national parks as museums or cathedrals and images of nature as a friend or relative” (p. 1); clearly adding an existential, self-defined element. As host to all of humanity, nature
traditionally transcends modern interpretation, often existing inundated with both ecclesiastic and secular elements. As a forum for personal enrichment, Elizabeth Tisdell (2008) acknowledges the encrypted spirituality that can be embraced from adult learning experiences; particularly those occurring beyond classroom walls. “Spirituality,” states Tisdell, “has historically had quite an important influence in the adult education field, though often the connection has been more implicit (p. 29).”

To understand the continuum along which definitions arise, one need only type “what is outdoor education” into a Google search engine and scour through some of the 27,200 pages retrieved (Google, 2010). What one quickly realizes, at first glance, are the eclectic array of settings that outdoor education may take place. The primary difficulty of arriving at a consensus of what outdoor education means is that the natural, existential, capital, and human resource of any outdoor education varies both geographically and over time.

The true task of defining outdoor education is made exponentially more difficult with the addition of one simple word, adult. The field of outdoor adult education is one that is rarely mentioned, rarely studied, and rarely defined. But if a new theory towards improving civic science literacy is to be address in the out-of-doors, the discipline, as it applies to this research, must be carefully approached. The succeeding discussion examines the evolution of academic thought in both the disciplines of outdoor education and adult education, individually, before approaching what outdoor adult education means and why such a unique construct is appropriate in the context of this research. Only after defining elements are merged with the urban cultural and social landscape can a precise framework for succinctly defining outdoor adult education be resolute.
Outdoor education is a general term that is often applied to activities and programs that are conducted in the outdoors (Priest, 1988), and the term is often used synonymously with environmental education, conservation education, naturalism, natural resource interpretation, outdoor recreation, outdoor stewardship, and an innumerable variety of other outdoor activities and education philosophies. Roughly coincident with a plethora of doctoral dissertations that emerged during the decade preceding World War II (Carlson, 2000), the discipline of outdoor education has evolved to mean many things to many practitioners and academicians. Whereas the meaning of outdoor education is the source of constant debate, it is fairly clear what outdoor education is not, formal classroom education. In conspicuously expounding upon this disconnect, Brookes (2002) explains, “A walker’s thoughts and mental associations while walking are not neatly assembled like the topics of a syllabus, different plants are not encountered in text book order, and creatures do not appear according to taxonomic rank” (p. 74).

One of the earliest attempts to define outdoor education was provided by Lloyd Sharp (1948) who was among the first to advocate outdoor education as an extension of public school curriculums. With industrialization at its peak in the immediate years following World War II, Sharp was concerned about the increasing population of youth in urban areas, the integration of diverging attributes among those youth, and the disconnect of urban youth from what Sharp called “the basic realities of life” (p. 314). Sharp believed outdoor education was a necessary component for both the personal and educational maturation of urban youth; a goal loosely aligned with practical science literacy. “If we are to preserve and extend freedom,” states Sharp, “the two basic qualities of understanding and self-reliance must be developed within each individual and far more
effectively and quickly than at present...much of our education can be secured more effectively in the outdoors by dealing directly with the environment and real life.”

Outdoor education was a means to this end. Sharp recognized that if outdoor education programs were to become more pervasive, so too must the definition of the outdoors. Sharp introduced an elementary baseline to meet his goal and emphatically stated, “the outdoors begins immediately outside the school building.”

Whereas Sharp clearly and succinctly defined the outdoors as he saw it, his notions of education, as well as the best curriculum and philosophy to meet that goal, was much more muddled. Sharp believed that outdoor education, specifically school camps, was “a necessary facility just as much as the library, the gymnasium, the auditorium, and the laboratory” (p. 315). The implication is that structured education was just as easily achieved, if not more practically achieved, when real life tools and cultural constructs outside of the school are used as educational resources. Ofsted (2004) adamantly supports this idea of outdoor education as an extension for school children enrolled in formal education. According to Ofsted (2004), “Outdoor education is a general term used to embrace different types of activity undertaken by primary and secondary students in a range of contexts” (p. 1). Sharp (1948) and Ofsted (2004) firmly believed that the outdoors, as a classroom, was an ideal way to revivify education through experiential learning, classroom group autonomy, and play. But is not a classroom in the out-of-doors the same as a classroom located in a school?

In contrast to the traditional notion of formal schooling at the time, Sharp (1948) felt that “Regimentation should be avoided” (p. 316). Sharp applied a more visceral philosophy to outdoor education in stating, “Primary emphasis should be given to helping
the [student] discover himself, his place in the group, his contribution to it, and his understanding of how people live together…it should give [students] a fuller understanding of our natural resources and should teach them to solve some of their own problems connected with man’s basic needs for food, clothing, shelter, group living, and spiritual self” (p. 316-17). These concluding attributes mirror practical science literacy and Sharp stood firmly behind research that demonstrated a student’s success, and consequential matriculation, as a result of his or her experiences with the out-of-doors. The outdoors was not simply a space for enjoyment, it served as an ideal classroom; enabling students to learn more quickly, have a greater appreciation for education, and retain knowledge for a longer period of time than if that same knowledge was procured in a more formal setting.

Two years following Sharp, P.J. Hoffmaster (1950) wrote an amenable article in which he felt that growing urban centers and the student’s lack of contact with nature and the outdoors is an important impetus for outdoor education programming. Unlike Sharp, Hoffmaster’s philosophy of outdoor education was a curriculum designed to instill the basic concepts of conservation; “a more wholesome attitude concerning property that belongs to the people and that was put there for their use” (p. 518). Hoffmaster continued, “I wonder, sometimes, whether – if children were just taken where the things of Nature are, out beyond the influence of great centers of population, and were given a limited amount of guidance and interpretation – it might not be the best and most effective way of getting into their minds a truer concept and fuller appreciation of the things we live by” (p. 521). The grammatical capitalization of “Nature” in Hoffmaster’s
quote, providing Nature a humanistic identity, speaks volumes to his personal constitution and passion for the outdoors and teaching conservation.

For Hoffmaster, defining the outdoors was a simple task; the outdoors was “where things are” (p. 521). This ambiguous identity of the outdoors provided Hoffmaster with an indiscriminate location for which practical science literacy and conservation education could be taught. “Without some contact there can be little or no appreciation of the outdoors and of the innumerable things and conditions that make up the outdoors” (p. 517). In a clichéd sense, the world truly was Hoffmaster’s stage.

Hoffmaster’s definition of outdoor is consistent with that of Sharp, as is his primary philosophy of education. Hoffmaster believed that the result of a successful outdoor education program is a student who “gained new understanding of his own worth” (p. 516). However, the curriculum and pedagogy to meet this end diverged from Sharp in that it was to encapsulate the domain of conservation. This curricular notion was revolutionary for its time and preceded the National Environmental Protection Act (NEPA) and organized conservation education by over two decades. “Land, water, birds, animals, and their relationships, each to the other” stated Hoffmaster (p. 521), “are different each day. To man, the changes, in most instances, are slow — hardly perceptible from day to day — and because of this apparent slowness, unusual methods of teaching (establishing concepts and understanding) must be employed.” Only through persistent contact with the outdoors, and a curriculum laded with student requirements to judiciously and existentially observe their role and position in nature, and within the greater community, can outdoor education become a fruitful endeavor.
A more recent twist on the ideology of outdoor education as conservation education is reflected in the environmental movement, which according to Weber (2000), “relies on decentralization, collaboration, citizen participation, and a holistic worldview that seeks to simultaneously promote environment, economy, and community” (p. 237). In writing about outdoor education through information procured through the British Ecological Society (BES), Becky Allen (2004) warns, “Without making outdoor education a statutory part of every child’s schooling, the government risks undermining its ability to tackle important environmental issues such as climate change.”

Allen (2004) defines the outdoors using the more academically refined term “fieldwork.” Moving beyond the general definitions of Sharp and Hoffmaster, fieldwork is going out into the natural settings of what it is you wish to study (Bogdan & Biklen, 2007). According to BES education officer Debbie Smith (as cited in Allen, 2004), “Outdoor classroom education allows students to connect abstract scientific ideas with ‘hands on’ experiences. Biological fieldwork may provide the only opportunity for students to observe living animals and plants in their natural habitat and promote a deeper understanding of the investigatory approaches that underpin the whole of science.” Finding outdoor education to be an ecological endeavor focused on environmental constructs and residential biota, the outdoors, as presented by Allen, can be defined as the forests, parks, wildernesses, and other natural lands society traditionally regards as protected and/or conserved. A more important attribute added by Smith is the idea that an outdoor education not only takes place in the outdoors and promotes practical science literacy, but it also emphasizes an understanding of scientific principles and processes.
The BES (as cited in Allen, 2004) claims, “outdoor education is so important that the government must make sure that it is a part of every child’s education by making it a minimum statutory entitlement.” With such concern on biodiversity and ecological dynamics, nearly all the rhetoric and consideration of outdoor education by the BES, including the education philosophy and curriculum, are centered on environmental protection, stewardship, and conservation. While the BES (2007) regards itself as an “active and thriving organisation [sic] with something to offer anyone with an interest in ecology,” their recommendations for outdoor education are geared specifically towards science students and science teachers. Nonetheless, we finally see the appearance of adults (“anyone interested” and “science teachers”) as an age demographic that can benefit from outdoor education.

Among the first comprehensive synthesis of what is specifically meant by outdoor education was conducted by Phyllis Ford (1986). With the support of the Office of Educational Research and Improvement, the case study explored several geographical, cultural, historical, educational, and social constructions of outdoor education. The culmination of Ford’s research led her to agree with early researchers, such as Donaldson and Donaldson (1958, p. 63), and conclude that, “outdoor education is education in, about, and for, the out of doors” (p. 2). From Ford’s perspective, “This definition tells us where the learning takes place, the topic to be taught, and the purpose of the activity” (ibid.).

If Ford’s definition seems a bit vague and tautological, it is for good reason. In her elaboration on the definition, Ford defines the outdoors as “any outdoor setting, from a school yard in an industrial neighborhood to a remote wilderness setting...Outdoor
education can take place on a walk around the block, or on a visit to a cemetery, a gravel pit, or an urban renewal project” (p. 3). The vague nature of what defined outdoors was a purposeful construct that, similar to Sharp (1948), seemed to include everything that is not a school building. However, Sharp was literal in defining in-school as buildings of formal education and the outdoors as everything, including buildings, beyond the structures of the school. It was believed that while an outdoor education needs to unilaterally take place in the outdoors, much of the planning and instruction was perfectly capable of taking place indoors (Parkin, 1988). Ford provided a major turning point in understanding both what it means to be outdoors as well as what outdoor education encapsulates. No longer was the relationship of traditional societal notions of the outdoors and outdoor education implied (Priest, 1986). Not only does outdoor education have to be “in” the outdoors, as traditionally defined by American society and discussed as “fieldwork” by Allen (2004), but it need necessarily encapsulate the interrelationship of human beings and all of nature (Ford, 1986).

Whereas at first glance Ford’s definition appears to get us no closer to defining the outdoors, the beauty of the definition lies in the succinctness of defining not only outdoor education’s innumerable outdoor “classrooms,” but also its purpose as it pertains to curriculum. “Outdoor education,” as Ford (1986) stated, “is in, about, and for, the out of doors” (p. 2). As such, outdoor education should embody a curriculum unilaterally centered upon the outdoors, “about,” with a philosophy of elevating student awareness of ecological dynamics and their position within the natural system, “for.” Ford elaborates on this by stating that a student of outdoor education should not only learn about the outdoors, in the outdoors, but also learn “the cultural aspects related to the natural
environment...[for] the purpose of developing knowledge, skills and attitudes concerning the world in which we live” (p. 3-4). This task can be completed in a traditional sense (with formal instruction) or through “outdoor activities people pursue during their leisure time,” states Ford (p. 4). This is the first clear separation of the traditional human educator-learner union in the outdoor education literature. While it is widely believed that education requires a human educator-learner relationship to be present, it is certainly not a necessity for learning “about, and for, the out of doors.” The key to the educational philosophy of outdoor education, as described by so many of the authors preceding Ford, is experiential learning. “It should emphasize experience by putting the native materials into the hands of the students at the spot where such materials are naturally found,” states Sharp (1948, p. 317).

Ford presents four philosophies for outdoor education. Her final philosophy, supported by Park (1984), is that outdoor education - experiential learning - is not just for grade school students. Outdoor education is “not just one field trip, 1 week at outdoor school, or even a once-a-year event,” states Ford (1986, p. 10). Outdoor education is a continuous process with no demarcation for termination other than death itself. Adults should actively engage in outdoor education and pursue continued ecological knowledge throughout their lives (Park, 1984; Goodman & Knapp, 1981; Ford, 1986). But discussing “adult” and “adult education” presents a whole new construct towards an overarching theory of outdoor adult education. How do we define an adult in contemporary American society and what denotes adult education?
2.3.2 Adult Education

With an informal American birth during the Revolutionary Era, the field of adult education plays an important role in shaping the social and civic engagement of American adults – through power and control - within a dynamic democracy. Of course, the practice and boundaries of the field of adult education was not formally addressed until the twentieth century. In 1926, the American Association for Adult Learners (AAAL), established with the support of the Carnegie Foundation, was developed to assist adult learners to democratically control change and the social order those changes would impose (Heaney, 2000). The practice of adult education during the latter half of the century metamorphosed from a social practice ingrained in civic engagement and democracy to, as Heaney views it, a practice designed for “molding citizens to pre-existing social conditions” (p. 566). This shift within the field of adult education, intended or not, altered the democratic position of the adult learner from a tool to affect and change democracy to that of an individual molded to live within the existing parameters of democracy.

The breadth of research throughout the past century has sought to collate the variety of cultural and geographic constructions of adult education within a single, succinct defining statement. Perhaps the most widely accepted definition of adult education today, as presented by Sharan Merriam and Ralph Brockett (1997), is “Working with adults in some organized, educational activity” (p. 4). Merriam and Brockett elaborate to include that, “What is common to all notions of adult education is that some concept of adult undergirds the definition, and that the activity is intentional” (p. 8). But what does it mean to be an adult?
Several months ago I was presented with the assignment of defining “adult education.” While I knew that the meaning of "education" was consistently debated within epistemological circles, I felt the definition of adult was clear, as constructed by both society and federal law. I defined adult as both the minimum age often characterized by my students – 18 years of age or older – as well as the academic achievement and maturity anticipated by the university through their admission protocols. I also felt that if the law gives citizens the right to freely participate in democracy as a voting member of society at 18 years of age (U.S. Const. am. 26.), the correlation between my definition and the legal definition revealed some generalizability. Upon receiving my paper back, I was immediately confronted with the vagueness of my definition for adult. What about college students who are younger than 18 years of age? Do institutions of higher learning always make correct decisions in gauging maturity? What about academic integrity and success? Are individuals younger than 18 years of age who are tried, convicted, and incarcerated as adults truly adults? What about parenthood or being the primary guardian of a parent? Needless to say, I left more confused than I had arrived and continued to contemplate the vast array of situations in which a legally or socially constructed definition is not always applicable within a specific culture or subculture.

If one is to define adult education, or outdoor adult education as it is, one must face the very real social construction of adulthood. Ironically, the only thing that seems clear in the literature is that the definition of adult is unclear; no real academic consensus exists. One resounding theme across research is the attribute of maturity. Maturity, from a denotative standpoint, refers to time following the terminus of “natural growth or
development” (Stein, 1980, p. 826). This notion of maturity reflecting adulthood is supported by, and expounded upon, by R.W. Paterson. According to Paterson (1979), “Those people to whom we ascribe the status of adults may and do evince the widest possible variety of intellectual gifts, physical powers, character traits, beliefs, tastes, and habits. But we correctly deem them to be adults because, by virtue of their age, we are justified in requiring them to evince the basic qualities of maturity” (p. 13). While this definition, a correlation of legal age and behavior, may not be applicable across all cultures and subcultures, it has been a constitutional standard in the United States. If outdoor adult education is to improve the civic science literacy of adults, as well as to enrich and empower its participants to freely make scientific decisions both affecting their lives and participation in social and democratic processes, then outdoor adult education in the context of this research must adhere to both legally defined and behaviorally defined attributes.

A second aspect of debate to Merriam and Brockett’s (1997) definition of adult education lies in the concept of “organized, educational activities” (p. 4). The idea of education being organized is not trivial in American culture. The United States Department of Education (2007) boasts having 15,287 public school districts serving nearly 11 million students. Billions of U.S. tax dollars and thousands of levies support the highly organized, traditional, hierarchical schemes of each district and the organized, and standardized, curriculums they impose. But as is accurately relayed by Merriam and Brockett (1997), the disassociation of adult education and K-12 education has left the former struggling for resources; “expendable in times of financial exigency (p. 23).” As such, organization is not always possible in the traditional manner in which it pertains to
the American public education system. To better understand the possibilities for outdoor adult education, we must first demarcate and review the forums and activities of formal adult education and lifelong learning.

The academic discipline of adult education often references a tripartite when discussing the semantics of educational activities: formal education, nonformal education, and informal education. Formal education directly refers to organized, hierarchical institutions, both public and private (Merriam & Brockett, 1997). Institutions of formal education can be described along a continuum including everything from the technical-functional conception (formal education for the purpose of developing the self-direction and cognitive skills necessary to economically succeed in life), to the strict credentialist conception that, according to Hunter (1988), “has both Marxist and Weberian proponents, in which schooling is regarded as primarily a means of shaping and certifying people’s values, attitudes, and habits, and only secondarily, at most, as a mechanism for imparting skills” (p. 753). While formal educational activities are an important, and increasingly pervasive form of adult education in America, they are not unilaterally associated with or conducted “in, about, and for, the outdoors,” as reiterated from Ford (1986, p. 2).”

“Informal education,” as presented by Merriam and Brockett (1997) is “generally unplanned, experience-based, incidental learning that occurs in the process of people’s daily lives” (p. 14). An abundance of literature on outdoor education and experience-based learning fills academic journals, but is largely considered circumstantial due to the lack of generalizability and validity associated with self-reports (Borrie & Roggenbuck, 1995). According to William Borrie and Joseph Roggenbuck (1995), “People may have
little awareness or memory of actual events, their own behavior, or the physical
components of the environment” (p. 2). A lack of introspective questioning, respondent
manipulation, and reliance on the respondent’s memory leads to reports that are nothing
more than memory constructions intended to appease researchers and avoid casting one’s
self in a negative light (Borrie & Roggenbuck, 1995). Regardless of these criticisms, the
value of informal education is unparallel in understanding both cognitive and ontological
development in adult learners. However, towards improving the civic science literacy of
adult learners in outdoor adult education activities, it is necessary for an adult’s
educational endeavors to have some manner of guidance from a qualified instructor;
without a strictly organized curriculum and hierarchical relationship.

Nonformal education more properly categorizes the educational activities that adults
undertake when participating in outdoor-based education. “Nonformal education,” as
defined by Joe Heimlich (1993) is “any organized, intentional and explicit effort to
promote learning to enhance the quality of life through non-school settings” (p. 2). Such
activities are undertaken on a voluntary basis, and often mirror the personal interests
and/or beliefs of the individual adult participant. The education personnel is hired for
their content knowledge and expertise; not their teaching skills. Additionally, nonformal
education activities can be plagued by persistent distractions as a wide-array of adults are
free to come and go as they please; often only concerned with their self interest (Taylor,
2006).

In addition to the preceding, Edward Taylor (2006) reports, “Nonformal education is
described as more present-time focused, responsive to localized needs, learner centered,
less structured, and an assumed nonhierarchical relationship between the learner and
facilitator” (p. 292), a sharp contrast to formal education. These complexities, among others, corner organizations offering nonformal education to consistently act and react, both to moment-by-moment in-class dynamics and general societal interests and concerns, if they are to ensure their survival (Horton & Freire, 1990).

Science and its application within the communities of America are very different from the science education received by today’s adults throughout their matriculation in formal education (Epstein, 1996; Latour, 1988, Roth & Lee, 2004). With formal science education having remained a relatively unchanged venue of didactic instruction laden with theories and seemingly inapplicable facts (Eisenhart, Finkel, & Marion, 1996; Roth & Lee, 2004), Roth and Lee (2004) advise that “it makes more sense to organize learning environments that allow students to become knowledgeable by participating in and contributing to the life of their community, which has the potential to lead to lifelong participation and learning” (p. 264). In short, it makes more sense that civic science literacy education performed in the out-of-doors for adults takes the form of nonformal education.

2.3.3 Nonformal Outdoor Adult Education

Humans have always had an affinity for the outdoors. The visceral human has sought to conquer nature for all manner of human existence, whereas modern man has evolved in fear; invoking a need to conquer as a matter of preserving one’s way of life or quality of life. But with media outlets extending their reach, outdoor-based scientific issues and concerns of social, cultural, and political interest have become more salient in American homes. The impediments of formal education and the increasing appetite of American adults to procure science-based ecological knowledge have led to an increased interest in
nonformal outdoor adult education. As a result of increasing visits and interactions with the out-of-doors, the number of nonformal education forums willing to provide outdoor adult education as nonformal education has continued to increase each year (Martin, Franc, & Zounkova, 2004). The culmination of these efforts, coupled with the preceding discussion, makes defining outdoor adult education a relatively simplistic and perhaps wordy task. As both a resounding theme in this paper and a foundation for the ensuing research, outdoor adult education is defined as nonformal education offered in, for, and about the out-of-doors for persons who by virtue of their age and basic qualities of maturity are legally enabled to freely participate in democratic processes and voluntarily choose to improve their science content knowledge for personal and/or political purpose.

Research demonstrates that today’s American adults lack the proper civic science literacy towards making both important decisions affecting their personal lives in a growing scientific society and making political decisions in a democracy underscored by citizen participation. Due to the present salience of the personal and political onus related to environmental and natural science decision-making, coupled with an American affinity for natural areas in the out-of-doors, nonformal outdoor adult education is an ideal forum for improving the civic science literacy of a freely participating adult populace. But how should civic science literacy, particularly an improved knowledge of scientific vocabulary and scientific processes, be taught to insure that knowledge transfer takes place and that the volunteer nature of adult education evades high rates of attrition? The answer to these questions lies in the paradigmatic perspective and research of James Coleman (1976) and his theory of experiential learning.
2.4 **Experiential Learning Theory**

Experiential learning theory has long been recognized as one of the preeminent forms of knowledge transfer and process understanding in adult education. The flexibility of experiential learning theory allows any place a human can stand or sense to be an educational setting and can be employed to address any learning need desired by the participant (student). Furthermore, experiential learning theory from a paradigm perspective can take on any number of forms that enable learning through immersion and action.

For Coleman (1976), immersion and action are only the first steps of experiential learning - a voluntary action on the part of the participant that serves as a stepping stone towards a personally desired, objective outcome. Reflection, generalization, and the understanding of overarching principles must follow in kind. “Experiential learning,” state Gordon Walter and Stephen Marks (1981) in support of Coleman, “is operative when participants are fully involved, when the lessons are clearly relevant to the participants, when individuals develop a sense of responsibility for their own learning, and when the learning environment is flexible, responsive to the participant’s immediate needs (p. 2).” When applied to nonformal outdoor adult education, civic science literacy, and the prevailing context of this research, experiential learning is the voluntary immersion of an adult learner in an out-of-doors learning environment to execute or observe an action, critically reflect on the effect(s) of that action, build generalizability, and develop an understanding of the overarching scientific vocabulary and principles towards improving one’s civic science literacy. The result of successful engagement in experiential learning can be demonstrated in a variety ways, and, as discussed by Barrett
need not be restricted to quantitative modes of evaluation or employing numeric symbology to demonstrate scientific understanding. “Restricting enquiry to those things that can be exactly measured would mean denying many of the benefits of alternative modes of inquiry,” states Barrett (p. 115).

Experiential learning in the mainstream literature has recently been associated with corporate training programs and professional development. Within corporate realms, employees are led through controlled activities designed to develop trust and improve interpersonal factors retarding productive relationships and holding companies from reaching their full potential in the marketplace. Common constructivist-based tools, including ropes, obstacles courses, and an existentially centered trainer, are utilized to construct a more productive group from the amalgam of socially and professionally disconnected workers. These “project approaches” have, at times, proven effective within the contexts of groups with narrow interests (such as within a specific industry or professional sector). “Yet all too often,” states Rosenberg (2007), “individuals attend team building programs only to return to the office with good intentions but no real commitment to apply new skills and behaviors” (p. 28).

The persistently negative outcome of these programs, attached to the adult education domain “experiential learning,” has, in large part, tarnished the luster of experiential learning in academic domains. But “project approaches” and “experiential learning” diverge quite widely in their purpose, design, and execution. Some of these differences stem from a misinterpretation of experiential learning on the part of practitioners, while others stem from alternative definitions of what experiential learning means. For example, some corporate training firms define experiential learning in a manner similar
to Walter and Marks (1981), in which “Experiential learning is defined as a sequence of events with one or more identified learning objectives, requiring active involvement by participants at one or more points in the sequence” (p. 1); a fragmented and incomplete notion of the educational process.

The basic tenet of experiential learning in outdoor adult education is that learning can be facilitated from concrete environmental interactions utilizing the human sensory organs. “If the experience is not concrete enough,” states Cheung (2006), “learning will be difficult” (p. 60). Psychologically, experience operates within aesthetic domains dominated by sensory information emanating from one’s immediate surroundings. “The acquisition of knowledge may thus be understood as a cognitive operation, or ‘sense activity’ involving relations between individual subjectivities and objective phenomena,” states Barrett (2007, p. 119). Through active experimentation, reflective observation, and abstract conceptualization, learners are empowered to discern between their existing knowledge - often manifested emotionally, subjectively, and absent of scientific understanding – and the objective knowledge produced through their experience (Barrett, 2007; Cheung, 2006).

2.4.1 Experiential Learning: A Historical Context

Whereas the academic literature on experiential learning is relatively young, its execution has been widespread throughout human history. Deeply rooted in both cultural and philosophical traditions, experiential learning has been employed for centuries as an essential means for personal growth and survival. But as is evident within the written chronology of Western history, experiential education slowly metamorphosed and emerged within an innumerable number of contemporary academic and professional
contexts with one of two primary identities: formal education or experience-based education. The disconnect between these prevailing philosophies, philosophies deeply rooted in classical epistemological writings, is as old as education itself; a notion supported by Houle (1977) who professes, “The distinction between formal education and instruction distilled in some fashion from raw experience is far from new” (p. 20). Towards understanding the value of experiential learning theory in a modern context, particularly as it relates to nonformal outdoor adult education within this research, one must understand the birth of education’s metamorphism in the eleventh century and how the contemporary experiential learning theory became emplaced in the modern body of academic literature.

As the eleventh century came to an end, the university emerged in Paris and Bologna, evolving from centers of professional training and the cathedral school to become a unified center of thought and general study. In the five centuries that followed, seventy such institutions emerged across Europe; each, states Houle (1977), “was a guild of scholars, teaching and studying a broad range of subjects and given an enduring life by a charter of incorporation” (p. 21). Today, universities are found worldwide, each with an educationally governed philosophy guided by the culture and social influence that is embedded within proximity. Yet each has retained some elements and vestiges of the Middle Age university, namely the premise that student mastery of subjects materializes from books and formal lecture. “Experiential learning, like common sense,” states Houle (1977), “had no place in the university curriculum. Even medicine was treated deductively” (p. 22). Due to the impersonal grounding of such ideologies, the approach was unable to establish objective validity in science. According to Polanyi (as cited in
Barrett, 2007), spatially isolated positivism failed to reflect the actual practice of science, and as such, “complete objectivity as usually attributed to the exact sciences is a delusion and in fact a false ideal” (p. 118).

Beyond the elitist, nonegalitarian universities and chivalric education of historical discussion, advanced education for the masses was carried out in a variety of forums designed to invoke mastery from a series of experiences. The earliest formalized experiential learning was carried out by craft guilds. Young men, eager to acquire a career and learn a trade, entered apprenticeship training. The apprentice matriculated, totally immersed, through every technical and aesthetic facet of his chosen trade; hoping to become a journeyman, and ultimately, a guild member and master himself. According to Houle (1977), “The apprenticeship system was based at every level upon experiential learning of the most immediate and practical kind and therefore differed very sharply from the teaching of the university” (p. 23).

As the Civil War came to an end, the rise of American industrialism and a growing literate population in the United States saw American universities and colleges begin to flourish. The traditional pomp and circumstance that engulfed universities and colleges transformed into the undertaking of traditional, but, content antiquated forms of education including the experiential apprenticeship. But the older forms of experiential learning that had been abandoned and commandeered by postsecondary education were initially given disservice. For example, agrarian and mechanical sciences in higher education, states Houle (1977) reflecting on early commentary, had “little useful content” (p. 28).
The transcripts of the 1871 Chicago meeting of college presidents unveiled the failure of linking experience and education towards experiential learning. As was judiciously noted in *An Early View on the Land-Grant Colleges* (as cited in Houle, 1977), “The student of pomology, for example, goes into the orchard and vineyard; the student in stockbreeding has the care of stock; the botanist works in the garden, and the mechanic in the workshop; and the young ladies, under a competent superintendent, do nearly all the labor of the kitchen, dining room and the bakery” (p. 28). The students of these wayward experiential learning attempts by American universities and colleges became nothing more than a labor pool with limited connection to the academic foundation intended; in this case, simply preserving the future commodity subsidence of the American populace. Students were displaced from the classroom, but held to institutionally fulfilling informal education philosophies, a philosophy that failed to circumscribe a true experiential learning theory.

As the twentieth century began to unfold, American universities and colleges began to understand the necessity of the merger of education and experience if knowledge transfer was to take place. Higher education officials outwardly decreed the realization that a distinction between learning and life had been made far too sharp. “We were not producing what we had hoped to produce in education,” reflected Virginia Smith (1977, p. xi), former director of Fund for the Improvement of Postsecondary Education. In the years that followed, stated Houle (1977), “Unknown compounds were analyzed by budding chemists, and engineering students surveyed areas of the campus” (p. 30). At Johns Hopkins University, medical professor William Osler required medical students to learn human anatomy and physiology at the university wards and through performing
autopsies at the local morgue. Eventually, states Houle (1977), “in profession after profession, the practicum or guided simulation became essential” (p. 30). In addition, students would no longer learn to simply explicate the dynamics and problems within their chosen profession through firsthand experience; they would learn how to be citizens. “By 1973,” states Morris Keeton (1977), “there had emerged a widespread movement towards the increased use of experiential learning theory to meet the needs of post-high school learners” (p. xvi).

But the consolidation of the theoretical and experiential came at a price. American universities and colleges had consolidated the two overarching curriculum goals to occur in a centralized location – the campus. An observation across American universities today too often paints the same picture, classroom-based laboratory work and poorly constructed practicum, clubs for the natural and physical sciences isolated to student halls, engineering testing on campus structures, mock trials held in law school courtrooms, animal observation from tanks and cages, the separation of medical education into pre-clinical and clinical years, etc. The theoretical, perhaps inadvertently, is no longer being explored and applied through the practical experiences of students within society and the appropriate context. The experiential has once again become educational on a formal level. In commenting on the resounding disconnect, Smith (1977) concluded that, “Experiential learning that takes place in real settings for real reasons may be far more multifaceted than campus-based experiential learning, which is usually less than life size” (p. xiii). In particular, the conventional approach to teaching science in the classroom has failed to mimic the true techniques and application in the real world; relegating these traditional conventions to the growing pile of ineffective
educational practices (Handler & Duncan, 2006); an absolute must to avoid if nonformal outdoor adult education is to garner success in improving the civic science literacy of American adults through experiential learning.

2.4.2 Experiential Learning: The Modern Theory

According to Gordon Walter and Stephen Marks (1981), “experiential learning is seen as a field in and of itself and not symbiotic with a single therapy, technique, theory, or methodology” (p. vii). Experiential learning theory separates itself from theories of instruction in that it is not a descriptive theory, but, as stated by Coleman (1977), “attempts to explain the psychological and physiological processes that take place when learning takes place” (p. 49), among other goals. Theories of instruction set forth descriptive actions for students, reified for institutional purposes, in the classroom environment where they are didactically guided through instructor-induced knowledge mastery. Experiential learning theory exclusively provides the groundwork for learning that takes place in out-of-classroom forums, forums where learners advance by acting on their environment and experiencing the consequence(s) of that action (Coleman, 1977).


Whereas theories of instruction have firmly rooted themselves in the educational literature, experiential learning theories have been largely overshadowed throughout the twentieth century. “Despite more than 35 years of advocating the use of inquiry-based
scientific activities [experiential learning] and curricula, the majority of current science education practices remain dependent on nonexperiential methods such as direct lectures and memorization,” state Handler and Duncan (2006, p. 9). Today’s teachers understand the interchangeability of the two general theories in optimally meeting desired education outcomes, but do not always apply them in the appropriate way to meet those outcomes. As an example, a professor recently shared with me a story of a middle school teacher who took her students to an airport so that the students could “experience” the subject matter. The students were seated on an airplane facing the pilot’s cabin where the teacher stood and gave her instruction. Students were to take notes on the teacher’s lecture and later return to the classroom where they would be tested on the material covered. As we discussed the teacher’s method, we unanimously agreed that the experiential learning excursion equated to little more than moving the classroom to a new location and applying the same mechanistic learning techniques. Everything about the step-by-step experience was guided by theories of instruction, not experiential learning theories. “The central tenet of experiential learning,” state Walter and Marks (1981), “is that one learns best by doing” (p. 1), not simply by being within an environment congruent with the material being studied.

Like any good theory, experiential learning theory must be transformable from the abstract to the concrete in practice. Forester (1989) reminds us that, “Theories do not solve problems in the world; people do” (p. 12). If experiential learning theory cannot guide a desired outcome within its participants, such as improving civic science literacy through nonformal outdoor adult education, it serves no fungible purpose in the development of social capital and becomes an academic relic for future study and
manipulation. Towards facilitating successful experiential learning, Coleman (1977) set forth a succinct, four-step guiding framework in which experiential learning proceeds inversely from the traditional modes of classroom education.

The first step of Coleman’s framework is immersion - students acting on the environment of study. In elaboration, Walter and Marks (1981) state that, “experiential learning is above all an action approach to change” (p. 151). The action process is the most fundamental doctrine of experiential learning. Action serves as the individual’s guide towards cognitive growth, a commitment to study, and as a catalyst for continued experiences and learning. “A novel experience,” states Cheung (2006, p. 75), “will trigger more learning.” Typologically, action can be broken down into four separate forms: experimental, exploratory, performance, and practice. According to Walter and Marks (1981), “Exploration refers to an individual’s action in an unknown, ignored, or avoided domain….Experimentation is an extension of exploration with the addition of thoughtful analysis and planning….Practice involves the active choice of behaviors possibly identified through exploration and experimentation…. [and] performance involves even greater commitment to open an action to one’s own and other’s judgements” (p. 152).

In the second step of Coleman’s framework, learners reflect upon the consequence(s) of their action, the cornerstone of experiential learning. Reflection gives learner’s the ability to both understand the effects of an action within a particular context, and arms them with a priori knowledge relevant to the effects of applying the exact action procedure anew (Coleman, 1977). As expanded by Freeman, Nelson, and Taniguchi (2003), there exists a need for reflection “in order to provide the learning experience with
an intrinsic value.” Such value, emanating from learner’s reflections and critical thoughts, not only assists in information gathering, but may also lead to a positive shift in the learner’s attitude, particularly as it relates to science (Handler & Duncan, 2006).

The third and fourth steps of Coleman’s framework, understanding and generalizability, are best discussed in unison. “The third step,” states Coleman (1977, p. 52), “is understanding the general principle under which the particular instance falls,” while the fourth step, generalizability, is “application through action in a new circumstance within the range of generalization.” Such generalization can only occur with experience. Students must test and retest their hypotheses regarding their action, and/or observation of an action, and reflect on each effect towards developing a wide range of knowledge covering even trace differences. As action begins to expand, the effects and reflection upon those effects begins to diverge and a concrete systemic understanding begins to evolve.

In summarizing these steps in the experiential learning theory framework, Coleman (1977) states, “Understanding the general principle does not imply…an ability to express the principles in a symbolic medium…It implies only the ability to see a connection between the action and effects over a range of circumstances” (p. 52). It is only after the fourth step, distinguishing the effects of multiple actions across temporally and spatially expansive experiences, and procuring the ability to successfully hypothesize the effects of differing action that the learning process ends with the learner being armed with a unified understanding of a principle that will be useful in the future.

Understandably so, learning through books, lecture, and other symbolic mediums in traditional formal education forums is an efficient manner of gaining knowledge. It is,
after all, the embodiment of centuries of experiential learning by all humanity that preceded the present. “Without it,” states Coleman (1977, p. 54), “each generation would have to traverse the whole path of civilization, and in truth ontogeny would recapitulate phylogeny.” But for all its efficiency, a traditional education, particularly formal higher education as historically reviewed by Houle (1977), has failed to arm students with both an understanding of dynamic principles and an excitement in their future intellectual quests. Additionally, it has failed to provide students with a level of contextual and content generalizability for the phenomena a student will later encounter, mainly a consequence of fragmented knowledge in the classroom. But such deficiencies are not a proclamation for the deconstruction of traditional forums of education. It is a declaration of the importance of first-person narratives in knowledge transfer, narratives that evolve from experience and a thorough contextual understanding.

Experiential learning, particularly in the natural sciences, is expanding worldwide (Maher, 2006), and can be, state Kidd and Kendall (2006), “characterized by learning through doing” (p. 63). The past two decades has seen a substantial increase in the level of research and scholarly writing on a contemporary experiential learning theory, and has revealed the universality of the theory in practice. Experiential learning is, notes Handler and Duncan (2006), “effective with a wide spectrum of individuals from different ethnic backgrounds, socioeconomic statuses, ages, and genders. Experiential learning, therefore, may be the ideal way to reach students that have lost an interest in science or students that have difficulty learning in traditional classroom settings” (p. 14). In addition, experiential learning provides educational convenience, subject complacency, and learning opportunities that are absent in traditional pedagogical approaches (Marando
& Melchoir, 1997), all attributes that both characterize experiential learning theory as an ideal epistemological theory towards improving civic science literacy and executing nonformal outdoor adult education programming.

2.4.3 Case Studies in Experiential Learning

Throughout its expansive history, education practices have been consistently characterized by debate and subjective measures on best meeting desired learning outcomes. Given the dynamics of educational policy over the years, often absent of student input, there remains no shortage of opinion over the ideal educational theories and forums towards meeting desired learning outcomes. “The educator’s challenge,” state Blunsdon, Reed, McNeil, and McEachern (2003, p. 43), “is to discover ways of teaching…that stimulate student enjoyment, while fostering learning.” Whereas an unending number of pedagogical approaches have been explored and applied, the idea of education being entertaining is typically shunned. Even within the realm of experiential learning, state Blunsdon et al., “What we do not want is an entertaining experience that produces no learning” (p. 44). However, other perspectives contend that without an element of entertainment, experiential learning may experience attrition – particularly as it relates to adult education. The central question that arises is can the two, experiential learning and entertainment, exist in unison and meet educational goals?

When it comes to America’s grade school students, public school districts have traditionally tended to err on the side of caution, isolating experiential learning to traditional supplemental forums such as museums, zoos, and aquariums. These forums have long been criticized as nothing more than “edutainment,” states Caulston (as cited in Hall & Bannon, 2006). Fortunately for adult learners, a volunteer student by definition,
the notion of education being “entertaining” is often viewed as a must as opposed to an option. Blunsdon et al. (2003) find that in addition to encapsulating the three primary goals of “skill application, knowledge acquisition, and increased understanding (p. 44),” goals with elements of overlap when held up against Coleman’s (1977) theoretical framework, experiential learning should be an enjoyable (entertaining) experience even if “one’s appreciation of ‘the learning experience’ (cognition) might occur at a much later point” (p. 52). But does a student’s enjoyment of experiential learning have a positive effect on learning outcomes?

The preceding question laid the groundwork for several studies of the much-ignored commingling of education, experiential learning, and enjoyableness during the learning process for adult learners. One such study by Blunsdon et al. (2003) explored a hypothesized positive correlation of enjoyableness and learning through a computer-based, temporally contained (three days), experiential learning program with undergraduate social science students. Overall, students reported enjoyment in both the use of computers and the overall learning experience. More importantly, a majority of students concluded the following: (1) having increased their computer skills, even if highly proficient in computers prior to entering the exercise; (2) having developed a general understanding of substantive theory, the subject of the experiential learning program; and (3) feeling they could apply the skills they learned to other domains.

As a controlled exercise presenting elements and activities that diverge from didactic instruction, one may simply contend that the results reflected the refreshing nature of an alternative pedagogical approach (computer learning compared to lecture and note taking). The study also failed to elaborate on all the elements of Coleman’s framework, a
necessary literary aspect for this research. But what the research does refreshingly indicate, returning to our preceding question, is that operative education outside of traditional pedagogy can be enjoyable and academically fruitful in unison – a primary goal towards preventing attrition during adult education activities. It should come as no surprise that the goal of improved civic science literacy as a result of nonformal outdoor adult education can only be achieved when the student is present and immersed. Experiential learning as a theoretical framework for nonformal outdoor adult education allows curricular modifications for both the educational and entertaining constructs across a variety of schemes that comprise the totality of the experience. Since different participants may find different aspects of the experience entertaining, the adult participants, as with the students of Blundson et al.’s (2003) study, must be presented with the totality of the experience first – Coleman’s notion of inversely proceeding – and then given explicit instructions for participants to immerse themselves in the area of the research experience that is most enjoyable for them.

With so many of today’s adults having been jaded by their previous academic experiences in formal science education, instituting entertaining and educational nonformal outdoor adult education still fails to insure that participants will improve their civic science literacy. Attrition prevention means very little to any adult education endeavor unless participants have a positive attitude towards the nonformal education instructor, the curriculum, and the knowledge transfer process grounded in andragogy.

A second benefit of experiential learning theory is its ability to regress negative attitudes carried by the participants. This attribute of experiential learning is demonstrated by Sharma, Lalinde, and Brosco (2006) in their recent research employing
experiential learning as a continuing professional education (CPE) paradigm towards improving the attitude of pediatric residents towards children with disabilities. The concern arose from the standoffish encounters of pediatric residents with children with disabilities in medical institutions, particularly during an encounter that was deemed an emergency medical situation. Such negative attitudes harbored by pediatric residents, unfortunately for the patient and the patient’s family, often reflected negatively in the quality of care residents provided in the emergency room. Medical research has continuously demonstrated that significant differences exist in the attitude of health care professionals towards children with disabilities as a function of cumulative experience. It was not much of a leap for Sharma, Lalinde, and Brosco to employ experiential learning theory to catalyze the interactive experiences and attitudes of pediatric residents.

Experiential learning as a paradigm towards changing attitudes through humanistic interactions has a metaphoric “corner on the market.” Elaborating on this notion, Sharma, Lalinde, and Brosco (2006) reflect on pediatric resident’s experiences; making clear that interactive attitude changes are “learned lessons that might be difficult to teach through didactic lectures or bedside rounds” (p. 188). This statement gives experiential learning theory a unique place in the literature by demonstrating its utility as spatially and temporally adaptable towards knowledge transfer and the understanding of processes that are not transparently available in textbooks. A second unique twist to this experiential learning module is the role of the parent(s) and disabled children as instructors, and their homes as classroom. This selection of instructors and classroom provided pediatric residents, and the greater academic community, immersion and action demonstrating the
adaptability of experiential learning theory, a theory capable of evolving and
metamorphosing for context-specific domains in the sciences.

One aspect of adult education that can never be ignored is the knowledge learners
bring with them to the learning experience (Knowles, 1989). Experiential learning theory
provides real experiences to develop, build upon, or transform learner’s knowledge
towards meeting a defined learning goal. Lamentably, as was demonstrated by the
pediatric resident’s behavior leading to the research, one’s content knowledge entering a
learning experience is often manifested emotionally, subjectively, and absent of scientific
understanding – a very real issue that contributes to a lack of civic science literacy among
American adults. For change to occur, states Rosenberg (2007), “individuals must take
personal responsibility to behave in ways that lead to success” (p. 28). As was
demonstrated by Sharma, Lalinde, and Brosco (2006), and echoed by Barrett (2007),
experiential learning has the ability to change both social attitudes and social practices;
leading to objective, scientific outcomes.

In addition to evolving a positive attitude towards science and scientific objectivity in
both personal and social matters, experiential learning theory has been demonstrated as
an effective in bridging the gap between theory and practice in scientific domains.
Continuous research in continuing professional education has unveiled positive
correlations between theory and practice accompanied by nonformal education;
invalidating traditional mechanistic approaches as the best method for learning healthcare
knowledge and skills. According to Kidd and Kendall (2006), “It has long been
recognized that an inconsistency exists between theory and practice and critical thinking
is essential for clinical practice competence” (p. 59). Towards meeting this goal,
instructors have sought more effective andragogical techniques, techniques that, more often today, align with experiential learning theory. In brief, state Kidd and Kendall, “more effective learner-centered education techniques are required (Ibid.).”

In presenting an example of the positive correlation, Kidd and Kendall examined advanced cardiac life support (ACLS), a necessary skill for all healthcare professionals (and arguably, for all individuals regardless of age or profession). As the most common medical intervention worldwide, it remains enigmatic why highly trained healthcare professionals are afraid to provide ACLS in emergency situations. According to Kidd and Kendall (2006), “Current methods of ACLS training have been criticized for lacking realism and, therefore, of having little relevance or value in the clinical setting” (p. 60). Just as many have long contended that one cannot learn to fly from a book (you have to get in the cockpit with a trained pilot), or learn to drive from a lecture (you have to get behind the wheel with an experienced, licensed driver), Burton (as cited in Kidd & Kendall, 2006) contends, “you can’t learn ACLS in front of a computer monitor” (p. 60). ACLS and the accompanying knowledge needed to perform it effectively is a practical skill that is best learned through practice accompanied with nonformal education.

In adopting an experiential learning theory in the domain of ACLS, several variations have been suggested. Some believe educational practices should be completely transformed into experiential learning while still others believe a mixture of didactic teaching methods and experiential learning is best. Other debates surround the ideal learning environment, use of technology, and group size for effective ACLS education. Regardless of the semantics relevant to ACLS, experiential learning is the common theme in providing more effective ACLS training and education that improves learning,
knowledge, knowledge recall, reflection, process understanding, and, ultimately, practice. According to Kidd and Kendall (2006), “the experiential learning techniques [in ACLS] successfully addresses the cognitive, affective and psychomotor domains of learning, consequently resulting in deeper learning” (p. 63). Just as ACLS learners have the opportunity to learn both theory and practice, bridge the gap between the two, and become more effective practitioners in the field, participants in nonformal outdoor adult education implemented towards improving civic science literacy must be able to become more effective, scientifically-enabled citizens aware of both the theoretical nature of science, the practices of science, and the practitioner vocabulary and processes that bridge the gap between the two through their experience. But is this asking too much from the average adult citizen who electively chooses to participate in nonformal outdoor adult education programming? Not according to 45 high school students asked to immerse themselves in the Pacific Ocean with dozens of hammerhead sharks, members of the family *Sphyrnidae* known for their cephalofoil heads and mariner accounts as a man-eater!

As a technique for improving the future science literacy of adults, Handler and Duncan (2006) suggested implementing more experiential learning in K-12 education. “If students are not permitted to experience this analytical process, they may ignore, reject, exclude, or reinterpret new information to which they have been exposed,” state Handler and Duncan (p. 10). In many cases this negative attitude towards science, which is manifested as a student, is carried will into adulthood and acts as an impediment towards the development of civic science literacy. While focusing on grade school student has no direct impact on improving the civic science literacy of today’s adults,
successful programming in a variety of K-12 science domains today allows a baseline to be developed for what type of experiential learning science programs adults are capable of participating in. Nowhere in the literature is the baseline elevated to a greater degree than in the Juvenile Scalloped Hammerhead Summer Shark Tagging Project (JSHSS) through the University of Hawaii, an experiential nonformal outdoor education program in which students both performed and assisted on a number of pieces of research requiring direct interaction with hammerhead sharks.

The five-day JSHSS experiential learning program was developed and executed to not only increase the science knowledge of students as it relates to hammerhead sharks and their ecosystems, but as a pedagogical technique capable of creating objective reflection, critical thinking, scientific understanding, and an improved attitude towards science; results that are expected through experiential learning theory across all ages. The premise of employing experiential learning was to allow students to learn through immersion and action (Handler & Duncan, 2006) - not just through reading, lectures, and other didactic methods - and follow those actions with understanding and generalizability in the science domain.

Forty-five high school students in the JSHSS were educated through a combination of formal classroom learning (considered a necessary forum for high school students) and experiential learning immersions. Over the course of the program, students were required to catch hammerhead sharks, identify their sex, measure, weigh, tag, determine the umbilical scar condition of juveniles, collect climatological data, depth data, global position system data, and perform a number of other duties that familiarized them with scientific equipment, scientific processes, and the scientific method. Students were
encouraged, and in some cases required, to provide feedback that led to the modification of the curriculum when necessary (Handler & Duncan, 2006), an andragogical construct deeply rooted in adult education. Student actions during the program was organized, and at times, scheduled. Actions not only included those of the student, but the meticulous observation of the direct action of others. Survey methods were employed to assess the student’s progress towards developing the desired science knowledge, and more importantly, understanding of skills and concepts outlined in the program goals. The resultant measures allowed researchers to conclude that student skills and concept learning improved. More importantly, Handler and Duncan elaborate (2006), “Student participants retained scientific concepts and skills they learned” (p. 14).

The results, as would have been expected had the program been executed for adult learners, demonstrate that students improve their content knowledge and recall, and are able to teach domain specific knowledge on hammerhead sharks and general scientific processes to others. This latter result is certainly not a trivial one. With negative public sentiments towards sharks, particularly the media-driven “man-eater” label for the hammerhead shark, student’s not only procured the necessary knowledge and vocabulary related to the hammerhead shark and its ecosystem, but also a high level of scientific understanding coupled with the self-confidence to remain scientifically objective in the face of critics and cynics. The student became civic science literate.

Experiential learning theory continually demonstrates the benefit of immersion and action of individual’s in procuring context specific science knowledge, developing an understanding of scientific processes, generalizability of knowledge into other scientific domains, and an overall improved attitude towards the science. The JSHSS proved a
valuable addition to experiential learning theory research in that there were measurable results and lasting impacts from the science partnership realized in a program of only five-days length; a program that all students involved in the study categorized as entertaining. Additionally, an overall sense of science and one’s role within a science-based society appeared to have materialized. “Because the shark research was a real scientific endeavor rather than a contrived exercise, students developed a sense of ownership, pride, and purpose,” state Handler and Duncan (2006, p. 14).

Experiential learning theory has continually proved its value in education as a mode for maximizing knowledge transfer, improving student attitudes, preventing attrition, creating lasting knowledge, building ownership of the content, and encapsulating each facet of the learning experience into an enjoyable experience. Additionally, it has proven an ideal theory for meeting and exceeding learning goals in outdoor education, nonformal education, and the mergence of the two; an ideal combination towards improving adult civic science literacy. Towards the continuous refinement of a working framework for this research, Brigham Young University’s Conservation and Outdoor Leadership Training (COLT) program was examined as an experiential learning program that closely parallels one of the most basic aspects of this research – the construct “outdoor adult education.”

The COLT program was first executed in the fall of 2000 by Brigham Young University as an extensive experiential learning program held in Aspen Grove, Utah. The program, state Freeman, Nelson, and Taniguchi (2003), “prepare[s] students by using experiential learning opportunities to provide safe and effective wilderness-based outdoor programs and to develop within its participants an ethical stewardship philosophy about
the land” (p. 25). Through a combination of classroom sessions (approximately 30 percent of the program) and constructivist-grounded field experiences, COLT program directors looked to improve both the land management practices (the learning objective) and the leadership skills (an important attribute in democratic systems) of students through immersion, action, reflection, and process understanding in the outdoors.

Experiential learning in the COLT program was strategically employed to offer students opportunity to problem solve, think critically, and communicate ideas through a set of meaningful experiences in the outdoors - the result of immersion not capable of being executed in a cramped, formal classroom on the BYU campus. The use of experiential learning theory was designed to induce several valuable benefits including both networking with land management officials to observe their actions, learn, and reflect firsthand on land management issues related to their field and creating field experiences capable of bridging theory and practice in context (Freeman, Nelson, & Taniguchi, 2003), an educational outcome emphasized by Kidd and Kendall (2006) in their ACLS research.

Throughout Brigham Young University’s COLT program, students provided both written and oral feedback (reflection) as part of formative evaluation after each experiential learning event in the field – a nonformal education tactic designed to break down hierarchical structures and allowed students to contribute to the educational experience, provide guidance for the next steps to be taken in the experience, and to share elements of their evolving scientific understandings that may have an impact on the greater society. The program was concluded with a summative, written evaluation (Freeman, Nelson, & Taniguchi, 2003) – an additional nonformal education construct
allowing present students to lend curricular and experientially-based decisions that would guide future programs. With the central tenet of providing students an outdoor education experience bringing scientific theory and practice into the proper context, the executed experiential learning theory within COLT, similar to a JSHSS outcome discussed by Handler and Duncan (2006), enabled students to better internalized and retain what they had learned from the complementing classroom experience. In opposition to rote memorization and the regurgitation of content knowledge, students applied their classroom experiences to real life experiences, internalizing the various domains learned into meaningful, context-specific knowledge that became part of the student’s identity. Student immersion in the outdoors gave them a positive opportunity to experience life, not just prepare for it.

2.4.4 Summatting and Building Experiential Learning Theory

Experiential learning posits that learning proceeds from acting within an environment where personal interest and experience catalyze human cognition, knowledge acquisition, and a concrete understanding of principles related to the experience. Throughout the literature undergirding experiential learning theory, positive outcomes in a variety of contexts are a resounding theme. In fact, Freeman, Nelson, and Taniguchi (2003) believe the success of experiential learning theory in outdoor education, particularly those involving adult learners, “makes legal issues and operating costs secondary concerns when compared to what these programs can accomplish.”

What all these programs demonstrate, as was discussed by Coleman (1977), is that experiential learning cannot be disconnected from some form of classroom education. These classrooms can be traditional formal educational settings, as was demonstrated by
Blunsdon *et al.* (2003), nonformal educational settings with didactic instruction (particularly for K-12 students and continuing professional education), or the mainstream nonformal educational forum where a nonhierarchical classroom consistently acts and reacts to moment-by-moment in-class dynamics and general societal interests and concerns that help shape and metamorphose the curriculum as it progresses. Nonformal education forums, explored in depth to demonstrate its ideal position in experiential outdoor adult education, also relies on classroom instruction to cater to participants with no previous content knowledge entering the program. This adaptation allows the maximum audience to be reached (a large one given the statistical review of science illiteracy among our adult population), often with those lacking content knowledge bringing an often-unexpected positive aura that can affect the whole group. In reviewing an experiential learning project and addressing this potential, Rosenberg (2007) states, “Prior to the session, participants knew very little about what they were about to experience. This fueled anticipation and excitement” (p. 27).

Any way one envisions the knowledge transfer process through experiential learning theory, there is never a complete disconnect from the classroom. To do so would be to eliminate the importance of context preceding, during, and following the experience. “Knowledge produced through aesthetic experience is always contextual and situated,” Barrett reminds us (2007, p. 115). The classroom also serves as a central forum for personal safety, ecological awareness, and field methodology instruction prior to embarking on the experience, as well as a place to share actions, scientific understanding, and develop generalizability and maximum knowledge acquisition relevant to
compounding field results and individual concerns towards developing civic science literacy.

With an understanding of the value of experiential learning theory in outdoor adult education, finding the ideal forum towards elevating the civic science literacy of participants is not a trivial matter. Such forums must not only enable experiential learning to occur in its entirety, they must also necessarily encapsulate theories of andragogy in the execution of nonformal education. According to Knowles (1980), andragogy is “the art and science of helping adults learn” (p. 43), and carries the underlying ideology that adult learners possess attributes as learners that separate them from children. While andragogy as a principle of adult learning is “appropriate for all adults regardless of subject content, setting, or purpose,” state Pratt and Nesbitt (2000, p. 120), not all forums are congruent with experiential learning theories. One forum that may serve as the ideal converging ground for outdoor adult education, nonformal adult education, and experiential learning theory is citizen science programs.

2.5 Citizen Science

For over a century, scientists within academia and other professional, scientific organizations have solicited the general public to collect valuable research data that would otherwise be spatially, temporally, and/or financially prohibitive to secure. The utilization of the general public as a research tool for on-going scientific work has recently been dubbed citizen science, an emerging paradigm in scientific circles. Citizen science, state Cooper, Dickinson, Phillips, and Bonney (2007), “engages a dispersed network of volunteers to assist in professional research using methodologies that have been developed by or in collaboration with professional researchers…[and] The public plays a role in data collection across broad geographic regions (and often, over long
periods of time), usually to address questions raised by researchers” (p. 11). To use volunteers from the general public not only serves as a tremendous pool of human resources in the acquisition of scientific data, but the apportionment of volunteers allows researchers to address ambitious problems without spatial or temporal boundaries.

As a catch phrase for any organized scientific endeavor that utilizes volunteers, many of whom have no scientific training, citizen science is soliciting volunteers on an unprecedented level to scientific projects owned entirely, or in part, by a research institution. In a recent article on the topic, Cohn (2008) expands on the component of volunteers, calling them “field associates in scientific studies” (p. 193). Within the many defining roles of the citizen scientist is making and recording observations, making quantitative measurements, and using computational and thematic software for data collection and distribution. For their part, citizen scientists have the pleasure of knowing that they have contributed to research that would otherwise be unfeasible, and, hopefully, walked away with some knowledge of science. But the average citizen chooses to volunteer for a multitude of reasons that extends beyond being philanthropic with one’s time; reasons that often begin with science education. Unfortunately, this most valuable of the volunteer’s reasons for participation are rarely realized throughout the course of participation.

The general public’s appeal for scientific content knowledge often catalyzes their engagement in citizen science due their eagerness to enlist when a project is meaningful to them and expected to yield meaningful results. This is in sharp contrast to formal science education, and what Trumbull et al. (2000) term “cookbook classroom laboratories” (p. 268). The contrast is shared by Cooper et al. (2007) who, perhaps
unfairly, insinuate that volunteers have more to gain from research on a more expansive scale, accompanied by professional scientists, unlike “localized volunteer-based research projects such as watershed-based monitoring schemes or research projects that bring supervised volunteers to particular locations” (p. 11), without actually stating what it is volunteers will gain.

While the primary role of citizen science is to involve the public in data collection for institution-based scientific research through outlined project protocols, it is only assumed that citizen science volunteers must learn more about science and how research is conducted during the course of their engagement (Trumbull et. al., 2000). In evaluating a citizen science project on bird nesting dynamics, Evans et al. (2005) iterate how “The program was also a topic of conversation with neighbors, friends, family, and community groups for most participants” (p. 592). Without supporting measures to evaluate the veracity of such conversations, should scientific knowledge and civic science literacy be presumed to be a potential ancillary effect of participation or can it be realized as part of the primary goals?

As we progress through the twenty-first century, citizen science should no longer be viewed as just an efficient mode of data collection for the targeted good of an institution of science, science research, and the political stance of sponsoring institutions. There is no denying that the overarching goal of spatial, temporal, and financial efficiency emanated by citizen science and the volunteer participant’s role in data acquisition over vast areas for extended periods is of tremendous value to society-at-large. Through experiential learning accompanied with nonformal outdoor adult education, citizen science participants are in a prime position to be a primary benefactor of the research.
This is not to imply that spatially and temporally expansive research serving the greater scientific community should not be performed through the assistance of volunteers. As a tool, citizen science provides the necessary ductility to be molded towards specific purposes (Cooper et al., 2007). Citizen science participants should be enabled and empowered to take away more than a sense of satisfaction and diminutive knowledge relating to the subject being studied. Through the development of more spatially and temporally controlled citizen science programming, particularly in an urban area where a large pool of eager volunteers reside within a reasonable distance of nonformal outdoor adult education forums and science topics related to their everyday lives, experiential learning and nonformal outdoor adult education with a focus on improving civic science literacy can come to fruition - an evolution that can be clearly envisioned following a thorough review of the past, present, and future of citizen science programs.

2.5.1 Citizen science: The Future is Derived From the Past

While the term ‘citizen science’ may be relatively new in academic circles, the use of volunteers as a mode of data collection is nothing new to science. “Arguably, the contributions of amateurs to scientific discovery stems from the days of Galileo,” states the Cornell Laboratory of Ornithology (CLO) (2008). Indigenous populations provided invaluable data on native flora and fauna for scientists, both professional and amateur, during centuries of world exploration and discovery. Charles Darwin’s monumental work presented in The Voyage of the Beagle added tremendously to the world’s scientific knowledge and was aided, in large part, by the knowledge solicited and volunteered by the indigenous populations of the lands he visited (Darwin, 1989).
Since the early days of science and scientific research, states the CLO (2008), “more formal initiatives have developed to foster research collaborations between volunteers and scientists in communities and research institutions around the globe.” According to Cohn (2008), “The practice goes back at least to the National Audubon Society’s annual Christmas bird count, which began in 1900” (p. 193). The first Christmas Bird Count (CBC), developed by ornithologist Frank Chapman, was held during the 1900 Christmas season and involved 27 volunteer observers from the general public as data collection tools. The volunteers, representing 25 distinct areas within the United States and Canada, located, identified, and reported species and species counts to the National Audubon Society for population tracking.

The project gained momentum with the addition of eager volunteers from the general public throughout the twentieth century. During the year 2000 CBC, over 52,000 volunteers in nearly 2,000 distinct geographic areas participated in data collection. The project is controlled and regimented by researchers at the National Audubon Society who, among other set parameters, define the locations (areas are “counting circles” of approximately 175 square miles), the number of volunteers within a counting circle (a minimum of 10 spotters for data recording), the time frame in which counts can be made (currently defined as December 14th thru January 5th), and the assigned route which participants will conform to while in the counting circle (National Audubon Society, 2008).

One important aspect of the CBC that was neglected for years was the fact that volunteers paid a modest fee to be part of the research. For the 2008 CBC, volunteers paid a $5 dollar fee to participate. According to the National Audubon Society (2008),
“The count fees collected during each CBC helps to cover the cost of generating materials for compilers, producing the annual CBC summary issue, and maintaining the CBC Web site and database.” If a volunteer elected to perform observations and counts within a second counting circle, the fee would have to be paid again. The willingness of volunteers to participate and the culmination of over one century of volunteer research data has enabled the National Audubon Society to generate one of the most valuable ornithological population databases in the world and raise millions of dollars, from the volunteers themselves, to perform the annual research and simultaneously cover all administrative and research expenses.

Sam Droege of the United States Geological Survey (USGS) Patuxent Wildlife Research Center acknowledges that the CBC is commonly cited as the historical origin of what has become to be known as citizen science. However, Droege has been able to uncover several projects performed throughout the nineteenth century, such as the American Ornithologists’ Union’s (AOU) Lighthouse Survey, that may mark the origins of the modern citizen science. But is this truly the cornerstone of what we now call citizen science? The project Droege believes that may in fact be the first to utilize volunteers for large-scale research is Wells Cook’s Migration Record Scheme research. The Migration Record Scheme, started in the 1880s, was performed for over 70 years, utilized 3000 volunteers, and collected over eight million data records (Miller, 2007; Droege, 2007).

During the 1950s, Cornell University began asking volunteers from the general public to offer data for use in scientific research (Cohn, 2008; Bhattacharjee, 2005). Under the direction of Arthur Allen, founder of Cornell’s Lab of Ornithology (CLO), the CLO
hosted Monday evening seminars at which Allen would ask, and have confirmed by a show of hands, if audience members had sighted a given species of bird (Bhattacharjee, 2005). The audience’s replies, many of who were amateur ornithologists, were recorded and the data was used for larger scale population research.

Forty years later the CLO began Project Tanager, a large-scale project in which nearly 1500 citizen science volunteers performed data collection for a large-scale census of four species of tanagers. Over 240 species of tanagers have been identified, with the majority residing in tropical climates, but only four species (Scarlet, Western, Hepatic, and Summer Tanager) are known to migrate and take residence in the United States. The collective results of citizen science volunteer data enabled CLO researchers to draw several conclusions, including that forest cover was the primary regional factor of tanager populations in fragmented habitats (Bhattacharjee, 2005).

Shortly after the launching of Project Tanager, 9000 citizen science volunteers were engaged to help CLO scientists study house finches and an epidemic of conjunctivitis. With such a large, spatially distributed force of citizen science volunteers, the extent of the epidemic across the Midwestern and Northeastern states was mapped within months. Five years of conjunctivitis citizen science volunteer data, and continued research by a team of CLO scientists backed by a $2.4 million grant (awarded by the National Institutes of Health and the National Science Foundation) based on citizen science volunteer data, helped the CLO to develop models that could predict the spread of aerially transmitted bacterial disease (Bhattacharjee, 2005; Cohn, 2008).
2.5.2 Modern Case Studies

The Cornell Lab of Ornithology (CLO) was among the first institutions to make a concerted effort to involve the general citizenry in scientific projects with meaningful ends, including publications in peer-reviewed academic journals, data accounting within academia, and the scrutiny of the scientific community at large. In 1993, the CLO developed the first of several contemporary citizen science projects, collectively dubbed the National Science Experiments (NSE), to assist the CLO in collecting data and observations through the public’s assistance in guided programs. With financial backing from the National Science Foundation (NSF), the CLO recruited volunteers to draw sweeping conclusions on the seed preferences of North American birds (Trumbull, et al., 2000).

The Seed Preference Test (SPT), as it became known, was an ideal candidate for citizen participation in a CLO developed program. To begin, state Trumbull et al. (2000), “Ornithology is one of the few scientific disciplines to which amateurs can make significant contributions…ranging in difficulty from simple bird counts to complete surveys of birds and their habitats” (p. 266). Whereas the scientific ability of amateur ornithologists was never questioned, concerns did arise over their ability to freely participate in such an important scientific endeavor funded by the NSF. Preliminary research hypothesized that the enthusiasm of amateur ornithologists and a multitude of other motivational factors would lead ordinary citizens to participate in the SPT program. Among the more salient motivations included the companionship and fun derived by the citizen science volunteers working in field groups, support groups, and with the CLO, and the engagement in experiential learning. Other factors identified included the
amateur ornithologist’s passion to provide information that would ultimately lead to the preservation and conservation of birds and their habitats, and the opportunity to participate in an ornithological project that, as stated by Trumbull et al. (2000), “might develop deeper understanding about the nature of scientific inquiry” (p. 266).

Recruitment for the SPT began in the fall of 1993 and utilized several methods of solicitation. The American Broadcasting Company (ABC) heavily aided the recruitment when the CLO received a spot on the popular morning show Good Morning America. Within months, the CLO had over 17,000 volunteers with a diverse array of backgrounds in ornithological training and ability. According to Trumbull et al. (2000), “demographic data revealed that participants tended to be older and better educated than the general population, and that they also were interested in science…[the] median age was estimated at 49 [and] seventy percent of respondents held at least a bachelor’s degree” (p. 268).

Following recruitment, volunteer citizen scientists received SPT research materials, an instruction booklet describing the methods, and a variety of instruments and references through the mail. The information served to aid the citizen science volunteer in making scientifically accurate observations and recordings that could be efficiently relayed back to the CLO (Trumbull et. al., 2000). Perhaps the most important piece of material within the instruction booklet was information on the scientific method and an abridged science content review of the SPT research.

By the spring of 2004, nearly 5000 citizen science volunteers across North America provided the CLO with nearly 500,000 ornithological observations. The observations reported were specific, detailed, and robust - arming CLO scientists with far more desirable and usable data and results than initially believed could be acquired.
Noncontributing citizen scientists were contacted to learn about the compounding factors leading to the absence of their participation. Among the factors reported, as iterated by Trumbull et al. (2000), was “ill-health, moving to new homes, and inability to attract birds to their experimental setups” (p. 267).

After data reporting, citizen-scientists were kept up-to-date on the SPT project and data results through the CLO publication Birdscope. Article topics included the scientific method, ways for citizen-science volunteers to evaluate their own data, and lessons learned by fellow citizen science volunteers. Each article was designed to keep citizen science volunteers immersed in the topic, the content, and hopefully retain their participation (Trumbull et. al., 2000). As stated by Trumbull et al. (2000), “Participants were truly contributing to discovery” (p. 267), a fact that they need to be made aware of to insure their continued participation. Citizen science volunteers indicated that they were serious about their participation and, as was revealed by the CLO, “made additional observations about the microecology of their feeding sites or about animal behavior [around their sites]” (p. 274).

A major aspect of the SPT and other citizen science programs that separates them from formal science education is that the research was conducted without an instructor or classroom, and, as would be evident with formal education, volunteer data was not subjected to criteria that deemed it correct or incorrect. Additionally, volunteers were not required to participate in any formal or nonformal education lectures or knowledge growth sessions. This decision evades making participants uncomfortable, possibly increasing attrition, through activities including simple questions that may measure or judge any increased scientific knowledge or understanding as a result of their
participation. As such, educating citizen science volunteers through any means exceeding informal education (mailed print material including *Birdscope*) became an implicit state-of-affairs, believing that educating volunteers had little to no bearing on the results of the citizen science project. But perhaps the most disconcerting aspect of the research was the clear statement by Trumbull *et al.* (2000) who stated, “Ornithology is one of the few scientific disciplines to which amateurs can make significant contributions” (p. 266). The resounding belief of CLO scientists is that volunteers from the greater American citizenry are not capable of making scientific contributions to fields outside of ornithology.

Citizen science had been demonstrated on numerous occasions to be particularly effective for ecological research and monitoring (Cohn, 2008), science topics in which the citizen science volunteer brings some element of previous knowledge and personal interest, particularly in the field of ornithology. The CLO had recognized the contribution that volunteers from the general citizenry could make towards increasing scientific understanding and advancing the scientific research of the CLO. Building on their viability as a research tool - testing their previous knowledge and skills - the CLO developed the House Finch Disease Study (HFDS), an important undertaking towards understanding *Mycoplasma gallisepticum*; research that the general public would have traditionally been seen as unable to perform with scientific vigor.

*Mycoplasma gallisepticum* is an avian pathogen that has proven highly transmittable among house finch (*Carpodacus mexicanus Muller*) populations. Following the initial reports of *mycoplasma gallisepticum* among wild house finches in 1993, the Cornell Lab of Ornithology instituted the HFDS citizen science program in November of 1994. The
HFDS was an ideal citizen science project given the wide range of the house finch and its reputation as a commonly sighted and identifiable “backyard bird.” Citizen science volunteers were asked to collect valuable data relevant to host-pathogen dynamics and ecological components that influence mycoplasma gallisepticum prevalence. By recording and reporting temporal and spatial variations in the prevalence of the disease for the CLO, CLO researchers evaluated volunteer data towards identifying potential factors driving mycoplasma gallisepticum (Altizer, Hochachka, and Dhondt, 2004).

Citizen science volunteers often find themselves involved in research on what some might call a trivial level – simple observations, counts, and data recording. But the outbreak of mycoplasma gallisepticum found citizen science volunteers recording both general information relevant to the house finch and observation locations, as well as observing clinical signs of an avian disease that included ocular swelling and conjunctival discharge characterizing eye infections (Altizer, Hochachka, and Dhondt, 2004). Over the course of 77 months, citizen science volunteers provided over 300,000 avian observations, including 25,000 individual observations, used by researchers studying mycoplasma gallisepticum. Combined with avian census data gathered through Project FeederWatch (PFW), an additional citizen science project sponsored by the CLO with 40,000 individual participants since 1987 (Project FeederWatch, 2008), the lingering persistence and fluctuating prevalence of mycoplasma gallisepticum was identified in depth.

According to Altizer, Hochachka, and Dhondt (2004, p. 319), the “continent-wide scale [of the outbreak] has provided an unprecedented opportunity to examine seasonal, geographical and long-term temporal variations in the dynamics of this wildlife
pathogen.” Among other results, CLO researchers found that “changes in prevalence occurred over both long (years) and short (months) time periods,” and, “varied significantly among geographical regions,” state Altizer, Hochachka, and Dhondt (2004, p. 314). In fact, the combined data revealed that while the prevalence of mycoplasmagallisepticum’s magnitude and timing was regionally variable, the bacterial pathogen had not monotonically increased or decreased since its initial reports in 1993 (Altizer, Hochachka, & Dhondt, 2004).

Drawing upon the successes of previous citizen science programs and the massive amounts of data that has been acquired, the CLO has begun to readdressed previous studies performed on more spatially confined levels. This decision implicitly reveals that volunteer data is not just substantial, but reliable and valid as well; worth collecting towards reevaluating research that had been performed solely within the confines of the scientific institution. One such study was performed by Cooper, Hochachka, Phillips, and Dhondt (2006) towards expanding on previous research related to clutch size, hatching failure, and latitude coordinates.

As part of the Cornell Laboratory of Ornithology’s (CLO) staff, Cooper et al. (2006) explored egg viability constraints on eastern bluebird clutch size along both seasonal and latitudinal gradients. The researchers were strategic in utilizing volunteer data collected through the Birdhouse Network (BN) citizen science program executed by the CLO from 1998 to 2004. In accord with the protocols of the BN, citizen science volunteers had been collecting a wide array of egg-related data related to cavity nesting birds, including the eastern bluebird. Seven years of volunteer BN data included 7,231 observations of eastern bluebird nests and 32,567 eastern bluebird eggs - reported by 530 BN citizen
science volunteers. This data, an invaluable collection of spatially and temporally expansive observations and records, enabled the researchers to employ a number of statistical models towards testing several hypotheses that were previously incapable of being tested.

The results of the research, state Cooper et al. (2006, p. 228), “provide support for the hypothesis that high ambient temperatures common at lower latitudes and late in the breeding season reduce egg viability.” This overarching conclusion is just one part of an information-rich discussion on a wide-array of variables that affect fecundity, clutch size, egg viability, and hatching failure, among others. The expansiveness of volunteer offered data variables (selection pressures) having the capability of lending scientific vigor and understanding to consistent large-scale patterns in clutch size, hatching failure, etc., had Cooper et al. (2006, p. 228) contemplating the feasibility of, “future large-scale investigations into all the causes of hatching failure…” (p. 228). This statement, of course, implies that the ascendancy of scientific knowledge in this area may be reliant on having a greater number of citizen science volunteers collecting more complex and sensitive data than has been previously asked — a goal that has been demonstrated to be feasible based on preceding evaluations of volunteer collected data.

The CLO’s efforts to recruit and retain volunteers as data collection tools has proven an invaluable tactic towards collecting scientific data and developing a deeper understanding of scientific phenomena. This interrelationship between academia and the general public is unprecedented and has continued to evolve, as is demonstrated by the use of the general public in judiciously diagnosing and providing data related to mycoplasma gallisepticum and other avian diseases. The merit of volunteer efforts in
citizen science, as was demonstrated by the Juvenile Scalloped Hammerhead Summer Shark Tagging Project executed by high school students, demonstrates the ability of the general public to procure and provide scientific observations and data on a level previously reserved for trained scientists. While directly interacting and educating the citizen science volunteer is not a feasible goal for citizen science programming on an expansive level (consider the 5,000 volunteers participating in the SPT), nonformal outdoor adult education towards improving civic science literacy can be brought to fruition through the localization of citizen science programming. Several recent programs, including Road Watch in the Pass and the Tucson Bird Count, demonstrate how more spatially and temporally isolated programs can be executed.

Exercising a unique twist to citizen science, the University of Calgary’s Miistakis Institute (TMI) solicited volunteers to collect data on wildlife for a project that TMI was contracted to perform. Whereas the ethical dimensions of such a decision are contentious, the decision by TMI was later applauded as ingenious. According to Lee, Quinn, and Duke (2000), “[TMI] recognized that the local residents possessed a significant interest and level of knowledge concerning regional wildlife…[and] that a citizen-science research project would be highly beneficial” (p. 3).

Human and wildlife habitat continues to intersect throughout North America. Such increases have led to greater human-wildlife encounters, a convergence that is perhaps no more ubiquitous than on and around North America’s roads and highways which disrupt and fragment natural habitat. According to Lee, Quinn, and Duke (2006), “The horizontal flow of organisms and natural processes across roadways results in negative outcomes for both human and natural systems” (p. 2). Statistical analyses performed in
2002 revealed that Canadian roadways were the location of over 30,000 vehicle-wildlife collisions. In addition to the 1,887 human injuries and 23 fatalities that year, resulting data estimated total financial damages to be in excess of $200 million. Recognizing the need for highway reform, the Canadian government and their civil engineers looked to redesign both the approach and alignment of roadways in a creative manner. But evaluating thousands of miles of roads and hundreds of species of animals made the task of determining where to implement new safety measures a near impossibility (Lee, Quinn, and Duke, 2006).

To study the interface of humans and wildlife in a specific context requires a temporally controlled study, whereas the spatial constraints were governed by the location of Canadian roadways. In the case of the TMI project, the Canadian government was unable to negotiate the time, manpower, or financial resources necessary for such a study, particularly one of such importance that the conclusions would guide highway and infrastructure policy decisions. To procure the necessary data for guiding government decision makers, TMI was contracted. During the planning phases at TMI, a researcher driving home serendipitously realized that the most efficient approach to data collection was to involve those members of the general public who drive on the roads and highways being examined; those who also have the greatest interest in the study and its outcomes. The citizen science project became known as Road Watch in the Pass (RWP). But unlike other citizen science projects, volunteers would have to be familiar with and able to quickly identify the regional wildlife, and, as would later be implemented, able to use thematic software for data entry (Lee, Quinn, and Duke, 2006).
The RWP citizen science project was initiated, funded, and made operational in November of 2004. Similar to the citizen science projects that preceded RWP, recruitment involved print, Internet, personal communication, and media outlets to solicit volunteers. Volunteers were directed to a designated web site with links that provided the scientific purpose, importance, and data collection protocols for those who wished to participate. In addition to providing web tutorials on proper wildlife identification (informal education), a vault for collected data, and thematic output using a geographic information system (GIS) mapping tool, the web site served as a forum for keeping people up-to-date on wildlife data being collected.

Citizen science volunteers were asked to maintain their normal activities and simply relay information regarding the intersection of roads and wildlife as they traveled. When a wildlife observation was made, citizen science volunteers were to record the date, time, exact location (assisted with the GIS mapping tool), species observed, age, status (dead, injured, or alive), the animal’s proximity to the road, and any comments or additional observations deemed relevant by the volunteer (Lee, Quinn, & Duke, 2006). Once the volunteer returned home, they would visit the RWP web site and input the data. If a volunteer did not have access to a computer or Internet service, an automated phone system for calling in data could be utilized.

Throughout the first eleven months of RWP, 58 volunteers (approximately 1% of the total population within the study area) contributed 713 observations of wildlife crossing, or in close proximity to, roads and highways within the study area. To determine the validity of volunteer observations, wildlife mortality data recorded as part of RWP (including the date, time, location, species, age, and sex) was correlated with wildlife
road fatality data collected by the government highway contractor responsible for carcass removal. RWP volunteer data, including wildlife species, age, and sex identifications, was found to be highly consistent with the highway contractor. After combining all data, high observation zones (HOZs) and high mortality zones (HMZs) were identified along regional roads and highways for the purpose of affecting public policies relevant to the intersection of humans and wildlife. According to Lee, Quinn, and Duke (2006), “By recognizing the spatial disparity between mortality zones and observation zones, one can begin to examine the attributes associated with each in an attempt to improve wildlife crossing” (p. 6).

Similar to the SPT, BN, and other citizen science projects, volunteer participation was relied upon for completing scientific research for academia and other institutions. Unfortunately, the RWP project was also consistent with previous citizen science projects in that it neither provided formal or nonformal science education to volunteers, nor was such education considered important towards the research outcomes. Volunteers and researchers maintained a passive relationship, from great distance, throughout the research.

Part of the failure to address science education in citizen science programming, as was previously discussed, stems from an inability to even begin discussing educational needs when thousands of volunteers across the continent choose to participate. A second resounding belief contends that citizen science projects only attract volunteers who already have an amateur interest in the topic of study. The RWP program demonstrates that these beliefs are not always true and that nonformal outdoor adult education can be integrated into citizen science programming with positive civic science literacy.
outcomes. The RWP project was more spatially and temporally contained than many of its predecessors and involved only 58 volunteers, many who volunteered due to a vested interest in the topic of study and the civic science literacy required in the policy process.

The RWP project did excel in unveiling three attributes of citizen science that had largely been absent in the literature. The first was that volunteers are recognized as knowledgeable of science-based phenomenon in their communities and regions, perhaps to a greater extent than the researchers themselves. Secondly, volunteer data was used to inform public policy – a critical aspect of civic science literacy that could have easily evolved throughout the program. Third, the validity of volunteer data was statistically quantified through correlation analysis with highway contractor data and statistically quantified the veracity of volunteer collected data. These strides begin to reinvent what citizen science can be for both research institutions and the general citizenry, and how citizens can improve their civic science literacy by possessing a greater role in the collection of data that guides public policy.

As the push continues to perform spatially and temporally expansive scientific research, the demand for volunteers has increased exponentially. To remedy this problem, many institutions have centrally located their research efforts in major metropolitan areas; areas where the number of potential volunteers and volunteers with certain skill sets are located in great numbers. One recent study that developed an urban-based research project is the Tucson Bird Count (TBC). Established in 2001, the TBC was developed, states Rachel McCaffrey (2005), “to acquire information about the distribution and abundance of birds throughout the Tucson area” (p. 72), an area of the
United States largely ignored by the Breeding Bird Survey (BBS) and the CBC citizen science projects.

The TBC was not only designed to survey bird species in and around the Tucson area, but also employed a long-term goal of using collected data for identifying ways to both sustain those species and restore native species in the study area. To achieve these goals, the TBC employed a citizen science research methodology consistent with the BBS model of site areas and observation routes. Volunteers selected one or more route, often spanning an area of 10km$^2$ or more, and surveyed the route one morning during the peak-breeding season of species common to the Tucson area. By 2005, the TBC involved 772 sites on 72 routes and utilized the effort of over 150 volunteers (including the ancillary year-round Park Monitoring Program citizen science project) (McCaffrey, 2005).

As with the many citizen science projects that have both preceded and followed the TBC, citizen science volunteers were an integral part of the TBC research methodology. The volunteers, states Turner (as cited in McCaffrey, 2005), “can identify the 25 most common Tucson-area species quickly by sight or sound, is familiar with most other birds of the Tucson area, and may need quick reference to a field guide for certain less-common or difficult-to-separate species” (p. 74), abilities gauged through an on-line self-test at the TBC website. Throughout the project it was explicitly clear that the TBC should dedicate as little time and effort as possible towards recruiting volunteers, a remarkable edict given the invaluable role of citizen science volunteers and the collection of valid data. In fact, at no point in time was any face-to-face correspondence between TBC personnel and citizen science volunteers considered. Volunteers were responsible for taking the eligibility test, choosing their routes, collecting data using TBC protocols.
available on-line, and entering their data results at a website designed and maintained by the TBC. Volunteers who chose to follow the ongoing culmination of data were e-mailed updated results through the Tucson Audubon Society (McCaffrey, 2005).

Between 2001 and 2005, TBC citizen science volunteers provided 164,000 pieces of data on 212 bird species in the greater Tucson area. According to McCaffrey (2005), “Data collected by citizen scientists through the TBC has enabled the generation of detailed Tucson-area distribution maps for more than 200 bird species” (p. 76). The data has been used in a number of ways, including policy development related to land use planning in Pima County, the impact of the West Nile virus on Tucson bird populations, and the health of saguaro cacti effected by nonnative cavity nesting birds – policy areas demanding civic science literacy. Whereas the citizen science volunteers have provided an invaluable database towards advancing research and knowledge in avian sciences, all too often, as with the many CLO programs, they continue to walk away with little more than the satisfaction of having been involved in something larger; something that may be beyond their repertoire of scientific knowledge and civic science literacy (such as saguaro cacti health, human-based ecological impacts on avian populations, and avian impact in the transmission of the West Nile virus to human populations).

The spatially controlled TBC citizen science program demonstrated that marked advantages can emerge from spatially contained programs, just as the RWP clearly demonstrated that temporally contained citizen science programs can have marked advantages as well. The program location, a metropolitan area with expansive natural settings, also demonstrated marked advantages due to the “large number of prospective volunteers [that] are already in place,” states McCaffrey (2005, p. 78). But the TBC
failed to address the potential of providing nonformal education to volunteers, reverting to the pervasive assumption that citizen science volunteers already possess all the science-content knowledge they need. Due to the programs limited spatiality, volunteer network, and cross-domain science policy goals, the TBC could have been an ideal opportunity for nonformal outdoor adult education encapsulating experiential learning with an explicit goal towards improving the civic science literacy of participants.

Citizen science has continued to evolve over the past decade and is beginning to cross over into the dual role of research programming and education provider. The epitome of institutions working with citizen science volunteers to perform scientific research and provide education is perhaps no more exemplified than by the Neighborhood Nestwatch (NN) program sponsored by the Smithsonian Environmental Research Center (SERC).

The NN has two distinct yet complimenting objectives. The first was to engage citizen scientist volunteers in spatially controlled research designed to collect scientific data towards an improved understanding of avian ecology - a more traditional aspect of citizen science in which volunteers are recruited to collect scientific data towards a larger goal. But the second goal, state Evans et al. (2005), was to “foster scientific literacy and increased attachment to place in [the volunteer’s] local natural environment” (p. 589). This second objective was intended to promote an intrinsic personal interest in the local environment and to develop the citizen science volunteer’s personal interest in the conservation and politics of the local region in which they participated.

The NN began in 2000 and within one year’s time had amassed a volunteer citizen science force of 175 households. Citizen science volunteers collected data on eight species of birds and their predators for researchers of avian population dynamics and
ecology studying the species along a gradient of urban-to-rural area outside of Washington D.C. In addition, citizen science volunteers were asked to observe and collect data on the nesting behavior of the eight species being studied. Unlike previous citizen science programs, including those of the CLO, the RWP, and the TBC, SERC researchers encouraged communication and participated alongside volunteers on an annual basis. The goal of interaction was to both cooperatively collect site-specific sample-sensitive data and “foster” the improvement of the science literacy, conservation stewardship, and personal attachment to place of volunteers.

Researcher-volunteer interactions began on the first day of the NN program through a no-charge formal education orientation program. Volunteers were asked to attend the orientation where they were provided both written and verbal protocols for conducting their observations, recording and reporting data, and the general research focus. Contact information for e-mailing and telephoning the research scientists was also made available to volunteers. In addition, volunteers were informed that researchers would be making annual visits to their homes during the course of the research to band birds, record anatomical data, and collect blood samples.

Volunteer data reporting, bird banding, and anatomical data provided a large amount of information for SERC research scientists. However, quantifying the value of the secondary goals of the SERC (improvements in science literacy, conservation stewardship, and personal attachment to place) proved to be more of a challenge. Through interviews, surveys, and electronic correspondence, many aspects of the citizen science volunteer, including their ornithological and ecological knowledge, level of education, age, and NN experience was coalesced. The data revealed that regardless of
the volunteer’s level of science literacy and sense of place, “there is a great potential for increasing knowledge about science among participants,” stated Evans et al. (2005, p. 591). “Even the most experienced birders we interviewed reported learning something new about birds,” elaborated Evans et al. (Ibid.). And what about the citizen scientist’s sense of place? Evans et al. qualitatively evaluated and concluded that an increased sense of place by citizen scientists was present after one-year of participation. This increased sense of place included a heightened awareness of birds and their habitats, ecological dynamics of bird-predator relationships, the value of a homeowner’s property as a habitat for flora and fauna, and an increased sense of conservation and conservation awareness - a major achievement in science literacy and, in particular, civic science literacy. The successes of the NN, state Evans et al. (2000), “highlight the value of community science programs that allow citizens access to practicing scientists in the context of a shared project” (p. 592).

The NN program demonstrated that citizen science volunteers are capable of learning through their experiences in science-based research, an aspect of citizen science that has never been doubted when programs are spatially and temporally controlled to enable interactions between volunteers and research scientists. It is the science content knowledge and knowledge transfer methods that are worthy of debate towards developing a contemporary citizen science paradigm centered upon the mergence of experiential learning and nonformal outdoor adult education in citizen science towards improving civic science literacy. While researchers did visit the home of volunteers, their visits were strictly professional – banding birds, collecting blood, procuring anatomical data – although one can fairly assume that researchers were happy to answer
any questions the volunteer may have had. But at no point was transmitting science knowledge or improving scientific literacy a goal of researcher visits. In fact, beyond the program orientation, education of any kind was absent. Researchers simply anticipate that volunteers would take a personal interest in their local ecosystem, conservation, and local politics through their participation materials and distant interactions - a well-intended but misdirected goal to propagandize the institutions position on certain scientific topics instead of providing volunteers true civic science literacy towards drawing their own conclusions and making autonomous decisions; decisions that may one day be policy issues. Because the goal of traditional citizen science projects is to procure data through a volunteer network, not to establish and act as a forum for education, the importance of the facts and information embedded in this debate is viewed as an ancillary argument when evaluating the success of the program.

The Migration Monitoring Program (MMP), a citizen science project centrally designed and administered through the Gulf Coast Bird Observatory (GCBO), demonstrates one way to increase the civic science literacy of a spatially controlled population through nonformal education. The MMP was established towards making scientifically grounded decisions related to the conservation of habitat important to migratory birds in the Southeastern United States. The MMP utilized 104 citizen science volunteers to “observe, record, and share information about the geographical and temporal distribution of neotropical migratory birds,” state Hamel, Riley, Hunter and Woodrey (2005, p. 729). Each citizen science volunteer executed spatially and temporally controlled research methods, and recorded their data in an electronic database accessible through the Internet. With over 100 citizen science volunteers working in
unison, the MMP provided the GCBO with a large amount of data related to avian migration that would have otherwise been too cost prohibitive and highly implausible to collect.

The citizen science protocols executed through the MMP provided more leeway to citizen scientists, compared to other projects, by allowing the citizen scientists to choose an area of study that was of personal interest and/or convenience to the volunteer. The MMP did assist overly ambitious volunteers by asking citizen scientists to control the geographic area of their study to the extent that the area of study was able to be surveyed in totality within four hours or less. The four-hour limitation must encapsulate both the primary target of research (avian surveying) and secondary data collection including weather variables, habitat analysis, and surrounding land use (Hamel et al., 2005). Additionally, citizen science volunteers agreed to repeat data acquisition on a weekly basis for a period of 10 to 15 weeks, depending on the migration season.

As with all citizen science projects included in this review, the recurring question is not what citizen science volunteers can do for the scientific community, but rather, what is the larger scientific community doing for citizen science volunteers? As of March 2002, 104 MMP citizen science volunteers, volunteering in 13 states and two countries, provided thousands of avian observations for the GCBO. These observations and the accompanying ancillary data have been beneficial to the mission and continued scientific work of the GCBO. As an example, the authors discuss how the 5,436 observations of 119 migratory species by one citizen science volunteer over a four-year period (270 hours) has been used to obtain support in both acquiring the land in the area of the volunteer’s study and making the necessary infrastructure improvements to that land.
According to Hamel et al. (2005), the data collected demonstrated the ecological value of the area as an “important stopover habitat for neotropical migratory birds in areas near the Gulf of Mexico shore and Caribbean Sea” (p. 731). But what benefit befalls the citizen scientists? According to the authors, MMP data takes a refreshing twist from other citizen science projects in that it has been applied to “community education” across the southeastern United States and the Caribbean basin.

Community education, as it relates to the MMP and GCBO, is an important way to improve the civic science literacy of the wider society on topics as condensed as neotropical avian migratory patterns to more encompassing topics such as how society and their activities effect weather patterns, suitable habitat within an ecosystem, and species survival. Community education, states Fasheh (1990), “is empowering and suited to the needs of the learners” (p. 19), an idea that is congruent with civic science literacy and the goals of data use by the MMP. Unfortunately for the citizen science volunteer, they are not the benefactors of the education, but the teachers themselves - offering MMP data “to their local communities as education,” state Hamel et al. (2005, p. 731). In addition, citizen science volunteers are encouraged to use their local data as “a powerful and credible stimulus for community education and local conservation activity…[and] become more active towards the conservation of migratory bird habitat in their communities (p. 731-32.).” While the outcome is discouraging at first glance, the MMP and GCBO clearly demonstrate how a major stride towards experiential learning, nonformal education, outdoor adult education, and increased civic science literacy can evolve within citizen science programming.
2.5.3 A Renewed Citizen Science Paradigm: Merging Program Strengths

As we progress through the twenty-first century, citizen science should no longer be viewed as just an efficient mode of data collection for the targeted good of an institution of science, science research, and the political stance of sponsoring institutions. In contrast, the citizen science volunteer is in a prime position to be a primary benefactor of the research through their experiential learning and nonformal outdoor adult education programming. This is not to imply that spatially and temporally expansive research serving the greater scientific community should not be performed through the assistance of volunteers. The additive argument is that citizen science volunteers should be enabled and empowered to take away more than a sense of satisfaction and diminutive knowledge relating to the subject being studied. Through the development of more spatially and temporally controlled citizen science programming, particularly in an urban area where a large pool of eager volunteers reside within a reasonable distance of natural areas offering outdoor education on science topics related to their everyday lives, nonformal outdoor adult education with a focus on improving civic science literacy can come to fruition.

The preceding review of citizen science programs demonstrate that a large number of citizens have an elevated interest in science to the extent that they will volunteer their time towards scientific endeavors (17,000 participants in the SPT program), that volunteers are valuable data collection tools with their extensive interest in the outdoors and the natural dynamics of their communities (the validity of data procured through the RWP program), and that citizen science can serve as a valuable forum for increasing the civic science literacy of volunteers (as concluded by researchers in the NN program).
The NN citizen science program also demonstrates that citizen science projects need not be spatially and temporally unbounded. The many facets of what citizen science is, coupled with emerging ideologies of what citizen science can be, builds a strong foundation for changing the face of citizen science programs while maintaining the core purpose of collecting large amounts of valid data that can advance, address, and solve scientific issues.

The idea of evolving the central value of citizen science programming was the primary foundation of this research by, not eliminating or revaluing the position of the volunteer in the research, but merging nonformal outdoor adult education with experiential learning within the programs towards elevating the civic science literacy of the science-content seeking volunteer. The renewed citizen science paradigm is the ideal program for solving the contentious debates between science and education as they continue to converge and collide on purpose, methodologies, program goals, and learning objectives in more traditional forums. It presents a unique win-win situation in which sponsoring institutions and researchers continue to procure data on a level otherwise unfeasible for the institution alone, and volunteers gain the valuable science content knowledge leading to elevated civic science literacy - for which they have turned to the citizen sciences to receive in the first place.

To address and seek remedy for scientific problems affecting the greater community without enriching, consulting, or empowering the volunteer community has begun to raise questions regarding the ethics of such programming decisions. These issues recently received publicity as they relate to university students performing university research funded and supported by external agencies under the umbrella of experiential
learning; particularly projects for which remuneration is being received by the research institution or the researchers themselves. “Ethical challenges seem to be less commonly discussed,” states Cooksy (2008), “however Eastmond et al. (1989) raised the issue of compensation…and Hurley, Renger, and Brunk (2005) discussed the implications of differing expectations on the part of the client, the student, and the instructor” (p. 340).

Expanding citizen science programming in a manner for which volunteers are remunerated with science content knowledge and broad-based education relevant to their community is, reiterates Cooksy, “a purpose that brings together expectations on the part of the client, the student, and the instructor.” Although the idea of citizen science having some form of educational benefit for volunteers has recently begun to receive attention, the use of citizen science as an operative forum towards an explicit goal of civic science literacy is a novel endeavor presented by this research.

There are currently over 200 scientific-based citizen science research programs across North America that utilize volunteers as data collection tools, although thousands more may exist. The National Science Foundation (NSF) is funding approximately twelve of these programs (Cohn, 2008), and according to David Ucko, deputy director of the NSF’s division for learning (as cited in Cohn), “Our objective is to increase public awareness of and participation [by volunteers] in science. Actually, we are more interested in the educational values than the research results” (p. 193). But, as has been briefly discussed, it is unnecessary to disassociate educational value and research results. Outdoor-based scientific phenomenon are now being scientifically explored on a spatially and temporally expansive level, but, points out Elnkat (2002), “One solution cannot be applied in different communities without taking into account social, cultural, political,
and environmental factors unique to each area,” (p. 3). In elaborating on this fact, Elnkat continues, “In many cases science gives answers to problems that could only be applied to a certain community with a certain level of development” (p. 3). For these issues to be addressed scientifically, intelligently, empirically, and efficaciously by a community (“a certain level of development”), the community must be armed with the necessary civic science literacy related to the issue. Nowhere can the education towards civic science literacy related to a science-based issue be obtained better than while immersed in the research that brings the issue to the forefront. Unlike the institutions commonly supporting geographically expansive citizen science projects, state Burke, Estrin, Hansen, Parker, Ramanathan, Reddy, and Srivastava, (2006), “Citizens have intimate knowledge of patterns and anomalies in their communities… enabling them to respond is both empowering and valuable to long-term research.” While the basic premise of citizen science programs is to perform geographically expansive projects over long periods of time that would otherwise be infeasible without citizen volunteers, there remain many scientific issues, including those that are more spatially and temporally contained, that would benefit from a new citizen science paradigm. It is the future citizen science volunteer, the eyes and ears of their local community or region of recreation, which possesses the greatest ability to identify issues and natural dynamics requiring scientific investigation. The new citizen science paradigm draws from the continuum of lifelong learning and should serve as a nonformal forum for outdoor adult education, a forum that is experiential, continuous, and in, about, and for, the out of doors (Ford, 1986).
CHAPTER III

METHODS

The purpose of this study was to demonstrate that a renewed citizen science paradigm utilizing nonformal outdoor adult education with experiential learning can improve the civic science literacy of adult volunteers while maintaining the central tenets of citizen science programming. Towards demonstrating the success of a renewed citizen science paradigm, the methods are designed to address the central research questions:

1. Can nonformal outdoor adult education incorporating experiential learning in a renewed citizen science paradigm improve the civic science literacy of adult participants?

2. To what extent can nonformal outdoor adult education incorporating experiential learning in a renewed citizen science paradigm that addresses and advances the civic science literacy of adult volunteers elevate the participation and assertion of those volunteers in social forums within a scientifically evolving democracy?

The methodology was carefully developed and considerations were made to insure that the research methods properly captured the necessary data to answer the preceding research questions, and do so in a manner that insures the highest levels of validity and reliability. Towards this end, the research begins by acknowledging one primary
assumption, the addition of a nonformal outdoor adult education component to experientially-based citizen science programming can have a measurable impact on both the volunteer’s development of civic science literacy and their willingness to assert their increased level of civic science literacy in social forums within a scientifically evolving democracy. As such, the research methods must be able to effectively measure outcomes related to both the nonformal outdoor adult education component (scientific vocabulary) and the experiential-based learning component (scientific process understanding) if it is to isolate and demonstrate the value of nonformal outdoor adult education in a renewed citizen science paradigm towards elevating the civic science literacy of American adults.

3.1 Introduction

The methods outline the collection of participant data through a two-phase process of self-report surveys and participant interviews, and how statistical analyses and analytical induction have been employed throughout data analysis to complement one another. Of 67 participating volunteers, 23 adult volunteers were purposively selected on the basis of their complete participation throughout the program. Data was collected through a concurrent mixed methods design, and both quantitatively, self-report surveys (n=23), and qualitatively, mixed method interviews (n=10), analyzed. The self-report surveys (Appendix A) are individual line items that asked participants to assess their knowledge on a pre-test post-test basis. The survey is straightforward and, at all times, directly related to the research as experienced and perceived by the participant. As relayed by Borrie and Roggenbuck (1995), “respondents often view the survey as a conversation [sic], and will not, for instance, reiterate information they provided earlier, nor offer information that they feel the research would take for granted” (p. 7). Participants were
given clear instructions on self-reporting throughout the survey instrument and were instructed to complete the survey at their own pace; with complete anonymity towards insuring the highest level of validity in the participant’s self-assessment.

The second phase of data collection was participant interviews. The interview consisted of both structured interview questions and unstructured interview questions. The structured interview questions were designed to be succinct, short-answer questions towards gaining knowledge ranging from the participant’s background, their own assessment of science in their personal lives, and the level of civic science literacy they assign themselves both prior to and following participation - covering a wider array of scientific domains than those centrally focused upon as part of this research. The unstructured interview questions were roughly sketched as a series of incomplete questions designed to procure specific data. Unstructured interview questions were both written in advance and concurrently created during the structured interview portion. This construct allowed for both a foundational structure to be in place towards facilitating the interview process and the melding of key aspects of the research and responses provided by the participants during the structured interview phase to be incorporated into the unstructured interview portion. Towards maximizing validity and reliability, both during and after the interview process, members check was employed for all participant interviews.

The concluding phase of the methodology was the data analysis towards elucidating the necessary data capable of answering the research questions. The first method is a quantitative analysis of self-report survey responses. Given the dependent nature of pre- and post-test scores drawn from participant responses to line items through the self-report
survey measure, a paired t test was employed to test the null hypotheses for statistically significant differences in civic science literacy elevations (science vocabulary knowledge and science process understanding) as a result of participation. The second method is a qualitative analysis of interview responses through analytical induction. The analytical induction process enables the necessary consideration to be given to the data and data analysis towards procuring a clear understanding and/or interpretation of the participant’s responses within the parameters of the research and the research questions. “Data analysis,” as Merriam (2002) reminds us, “is an inductive strategy. One begins with a unit of data and compares it to another unit of data, and so on, all the while looking for common patterns across the data” (p. 14). Data analysis was completed with a three-stage coding scheme that emerged. Towards insuring the validity of the emerging coding scheme capturing emerging patterns during analytical induction, peer review of all surveys and transcripts was performed.

3.2 Methodological Considerations

3.2.1 Research Protocols

An expansive review of the literature failed to uncover a single citizen science program dedicated to offering nonformal outdoor adult education (or any other form of nonformal education) to volunteer participants, either as a method of elevating the scientific vocabulary knowledge or science process understanding of volunteers through experiential learning during the course of citizen science programming. Understanding that a nonformal outdoor adult education component is unprecedented in citizen science programming, it is presently hypothesized to have a value. Data protocols can be approached from either a quantitative or qualitative perspective; both of which are
capable of lending credence to the research questions. However, following a review of nonformal adult education with respect to both a traditional and more modern perspective, the literature reveals a broadly accepted understanding that the world and the meaning that individuals construct in their lives through nonformal adult education programming is not a positivistic, measurable, fixed agreement lending research results to overarching conclusions of generalizable causation (Merriam, 2002). According to Merriam (2002, p. xv), “Understanding a phenomenon from the participants’ perspectives – the meanings people derive from a situation or understanding a process – requires asking important questions, questions that lend themselves to qualitative inquiry.” Barrett (2007) shares Merriam’s perspectives in his discussion of demonstrating successful engagement in experiential learning activities. As discussed by Barrett (2007), experiential learning research need not be restricted to quantitative modes of evaluation or employing numeric symbology to demonstrate scientific understanding. “Restricting enquiry to those things that can be exactly measured would mean denying many of the benefits of alternative modes of inquiry,” states Barrett (p. 115).

In a similar breath, quantitative methods do have their advantages in research, particularly when synthesizing large amounts of data towards a pointed conclusion. According to John Fraas (1983), “In the present atmosphere of accountability, it is important that educators be able to evaluate the effectiveness of educational programs, methods, and materials” (p. 1), an expounded goal implicating a best practice of both objective (quantitative) and subjective (qualitative) measures. Because qualitative data can be assigned numeric values and numeric data can be evaluated from a qualitative
paradigmatic stance, both forms can be classified and used to render meaningful results (Trochin, 2006).

With a conscientious goal of maximizing the validity of the data results, it is prudent to appease pundits from both side of the “quantitative or qualitative?” debate by analyzing the dichotomous scheme of self-report data through quantitative modes and interview data by analytical induction. Because the dichotomous scheme applied to self-report survey data does not measure against an unknown population, “the same subjects respond on two occasions,” Howell (2002, p. 192) elaborates, a paired t test is the best method to assess the two sample means for statistical differences. In addition to its usefulness given the form of the data, the t test is very robust, particularly with sample sizes exceeding n=10; “more or less unaffected by moderate departures from the underlying assumptions,” states Howell (p.215). A qualitative component is employed to explore the nature of participant’s meaning systems and understanding of scientific processes through a renewed citizen science paradigm incorporating nonformal outdoor adult education and guided experiential learning.

This research is designed to purposively select participants who have chosen to volunteer in a citizen science program. While volunteers are unaware of the constructs of the renewed citizen science paradigm to be employed, the research is centered upon the natural sciences and executed with the impetus of acquiring scientific data for the sponsoring organization, a basic tenet of citizen science programming, and identifying the construction of civic science literacy through the building of a personal repertoire of scientific vocabulary and science processes understanding.
3.2.2 Participant Motivation

A second consideration addresses the authenticity of the volunteer’s motivation and pursuits in citizen science programming. To insure the authenticity of the participant’s pursuits, each of the volunteers selected to participate in the research have freely chosen to volunteer for the facilitating organization executing the research and is willfully participating for purposes aligned with the citizen science program’s goals; not for self-recognition or honors as a volunteer. In addition to the element of nonformal outdoor adult education in the renewed citizen science paradigm, experiential learning - as its own academic domain – was addressed with the volunteers. By discussing what was directly expected from the volunteers before the program’s start, an andragogical construct, attrition was avoided and a best practice towards addressing research results related to science process understanding was able to proceed unhindered.

3.2.3 Experiential Learning

A final consideration is the addressment of experiential learning. Experiential learning, as a field of study, consists of three primary categories of research that, although often explored as unique entities, must be addressed in their totality towards understanding the value of the paradigmatic approach in cooperation with the construct of measures that capture science process understanding. The three elements of experiential learning that must be addressed include: a) enjoyment, b) learning, and, c) outcomes (Blundson, Reed, McNeil & McEachern, 2003).

The notion of enjoyment is far too often validated by the volunteer’s ongoing participation in any citizen science program, an inversely quantifiable aspect related to volunteer attrition throughout the program. But continued participation and/or attrition,
alone, does not tell the whole story. Adult learners, according to Malcolm Knowles (1989) are different from younger learners in that they are more “life-centered” (problem- or task-centered) in choosing to participate in educational programs (Merriam & Brockett, 1997, p. 15). Enjoyment does not need to be manifested in an emotional manner; particularly when the life centered motivations are being satisfied. When an experiential citizen science program addresses the enjoyment needs of volunteers, whether effectively or not, volunteers may continue to engage in the program even when andragogical constructs are not being employed. Such divergence from the mainstream thought of what constitutes enjoyment cannot be statistically assessed. An accurate assessment of enjoyment necessarily requires a dyadic forum where candid conversation can take place to address not only the participants decisions to continue or discontinue participation in a renewed citizen science paradigm, but the feelings and thoughts that self-validated their enjoyment in a citizen science program that spans over four months in duration. For example, a volunteer may have contemplated discontinuing their participation at several times throughout the course of the program only to maintain their participation under the auspices that the program will ultimately meet their enjoyment needs; needs that may or may not be ultimately realized following the program. Their continued participation is not tantamount to enjoyment, but anticipated enjoyment.

While enjoyment is important in maintaining participation and data veracity in any citizen science program, it is learning and educational outcomes that have the greatest value in this research and the greater realm of adult education literature. For decades, citizen science programs have neglected learning outcomes, and perhaps rightfully so. The goal of citizen science sponsoring organizations is not to serve as an educational
forum, but as a research institution that has developed means of addressing research problems requiring data collection beyond their budget, time, and staff feasibility. It is only assumed that citizen science volunteers must learn more about science and how research is conducted during the course of their participation in citizen science programming (Trumbull et. al., 2000). Similar to experiential enjoyment, if this research is to effectively evaluate learning it must employ a methodology that is both adult oriented and measures the anticipated learning gains of the participant, not those conceived by the sponsoring or facilitating organization. In discussing experiential learning, Blunsdon, Reed, McNeil, and McEachern (2003) advise that, “Our concern here is less with objective assessment of learning (as might be measured by grades and marks) than with students’ subjective judgment of their learning…[including] skill application, knowledge acquisition and increased understanding” (p. 44).

The final aspect of evaluating experientially based programs is educational outcomes. Citizen science programs have long been evaluated for success through the quantification of volunteer data, the veracity of volunteer data, and the overall success of volunteers as tools in meeting the goals of the citizen science program as defined by the sponsoring organization. A true evaluation of a participant’s educational outcomes, particularly as it relates to transfer-of-learning in personal and social forums within a scientifically evolving democracy, necessarily must address whether or not a participant believes they are able to apply what they have learned in other contexts (Blunsdon, Reed, McNeil, & McEachern, 2003). Such evaluations cannot be taken out of the personal context of the participant; therefore not measurable through Likert scales or statistically evaluated questionnaires.
While this research was initially conceived as a quantitative work, literature-based methodology reviews for best practice unveils the value of merging quantitative and qualitative methods towards the development of a solid foundation for data analysis and validity. The research is designed to purposively select participants who have freely chosen to participate in citizen science programming - programs that have traditionally excluded a nonformal outdoor adult education element - in the natural or physical sciences. The design systematically assessed the utility and value of nonformal outdoor adult education within the renewed citizen science paradigm towards both elevating the civic science literacy of participants and evaluating how their personal assertion of civic science literacy may address and advance their participation in a scientifically evolving democracy. To insure the authenticity of the participant’s pursuits and knowledge acquisition in a renewed citizen science paradigm, data was to be collected from two independent citizen science programs. The first program was to be a current research project with established volunteers who have participated in citizen science programs in the past. The second program was to be the redesigning of citizen science, the renewed citizen science paradigm, and include established volunteers of past citizen science programs as well as members of the general public invited to participate through print, electronic media, and word-of-mouth. Due to a lack of cooperation in melding the renewed citizen science paradigm into an established research project, only volunteers of the 2010 Research River Biomonitoring Stream Assessment (RRBSA) - a program meeting the guidelines of the “second program” - was included in this research. All experiential outcomes, both related to the renewed citizen science paradigm and data applicability, were drawn from this single citizen science program.
3.3 Paradigmatic Approach

Given the nature of the research question and the methods to be employed, a basic interpretive (descriptive) research design was approached from the interpretivist paradigm. Within this paradigm, understanding is facilitated through the researcher as an instrument, inductive strategies are employed towards identifying common themes and recurring patterns across data, and the culmination of data is highly descriptive (Merriam, 2002). In addition, internal and external validity are made more robust with “trustworthiness and authenticity (Denzin & Lincoln, 2000, p. 158).” While participants were solely chosen on the basis of their participation within the RRBSA (a purposive sample), assessing their elevation of civic science literacy requires an understanding of how nonformal outdoor adult education precipitated science vocabulary knowledge and a more enriching experiential learning experience that led to the construction of science process understanding and its meaning. According to Schwandt (2000, p. 191), “To find meaning in an action…requires that one interpret in a particular way what the actors are doing.” Within the context of this research, the interpretivist paradigm guided the methodology towards not only why individual volunteers choose to participate in citizen science programming, but also the meanings behind their action, the meanings developed from their actions throughout the program, the development of meaning that defines their civic science literacy, and both their potential and qualification for participation in social forums within a scientifically evolving democracy as a civic science literate member. As someone who holds multiple degrees in the natural sciences, and pursuing a doctoral degree in adult education, empathetic identification through an interpretivist paradigm allowed me to understand the subjective nature of the participant’s actions, and allowed
me to get inside their heads to, as elaborated by Schwandt (2000, p. 192), “understand what he or she is up to in terms of motives, beliefs, desires, thoughts, and so on;” particularly in the context of the natural sciences.

3.4 Data Collection

Research data was collected through a two-phase process of self-report surveys and participant interviews. With one of the most fundamental attributes of civic science literacy being an understanding of scientific vocabulary, careful consideration has been made as to the best measure to capture this data. While the interview process may be able to closely gauge changes in the participant’s knowledge and understanding of scientific vocabulary, the natural stress (for both the researcher and participant) and a phrenetic pace is capable of altering the validity of participant responses. Towards maximizing the validity of research results related to scientific vocabulary, particularly in giving participants ample time to reflect on their learning, participants were mailed a self-report survey instrument at the conclusion of the program. The survey instrument employed a dual four-point Likert scale designed to enable the participant to self-report their scientific vocabulary and science process understanding both prior to the research and following their participation in the renewed citizen science paradigm. The use of a Likert scale is a construct to lend clarity to the self-reporting process and not for the application of measurement theory or statistical analyzes that weigh the numeric values on an interval scale. Although asking participants to complete pre-research surveys following the program was a challenging prospect, Handler and Duncan’s (2006) use of this method revealed that, “students were capable of accurately providing information on
their own level of a priori knowledge as well as serving as reliable and valid judges of their own learning” (p. 14).

Self-reports necessarily need to be straightforward and, at all times, directly related to the research as perceived by the participant. As relayed by Borrie and Roggenbuck (1995), “respondents often view the survey as a converstation [sic], and will not, for instance, reiterate information they provided earlier, nor offer information that they feel the research would take for granted” (p. 7). Given the psychology offered by Borrie and Roggenbuck, the surveys were personalized for each participant and welcoming through its succinctness. Participants were given clear instructions on self-reporting throughout the survey instrument, and were explicitly instructed to complete the survey at their own pace and with complete anonymity - again, towards insuring the highest level of recall accuracy and measure validity. Participants were also provided with a self-addressed, stamped envelope for returning the survey in a manner that proved convenient for each participant.

The second phase of data collection is participant interviews. The interview consisted of both structured interview questions and unstructured interview questions. The structured interview questions were designed to be succinct, short-answer questions towards gaining knowledge on the participant’s background, their motivation for participation, their experience throughout the course of the program, their personal feelings regarding the nonformal outdoor adult education component, and to briefly assess their level of civic science literacy both prior to participation and following participation. The unstructured interview questions, while roughly sketched as a series of incomplete questions designed to procure specific data, were concurrently created during
the structured interview portion of the researcher-participant interaction and were centered upon key elements and responses provided during the structured interview process. Due to the personal association of the researcher and each participant that was expected to develop through the course of the program, complete written transcription occurred synchronously with the interview. While this procedural decision extended the interviews from approximately 30-45 minutes to 60-120 minutes, participants did have an immediate opportunity to read, and edit if necessary, their responses. The interviews were performed at a time and location comfortable for each participant, with scheduling performed through electronic mail, telephone, and face-to-face correspondence. Location decisions were made cooperatively with participants prior to the interview so that proper arrangements and technology preparation could be made for those participants choosing to communicate through protocols diverging from traditional face-to-face meetings (e.g. instant messaging (IM) on the World Wide Web, and blog communication). In addition, all participants were asked to read, relay personal understanding, and sign an Institutional Review Board consent form.

“An interview is a purposeful conversation,” state Bogdan and Biklen (2007, p. 103), “that is directed by one in order to get information from the other.” According to Merriam (2002, p. xv), “Understanding a phenomenon from the participants’ perspectives – the meanings people derive from a situation or understanding a process – requires asking important questions, questions that lend themselves to qualitative inquiry.” As discussed, the interview method employed in this research is a mixed interview method consisting of a series of structured interview questions, orally presented as a guided questionnaire, followed by unstructured interview questions. Structured interview
questions were presented along a time continuum related to the participant’s background and their experiences; beginning with general questions related to the participant’s background and followed by questions relating to personal and social science-efficacy in the participant’s life, motivation in participating in citizen science programming (evaluating the civic science literacy of participants both prior to and following citizen science programming participation), questions relating to the citizen science experiences (nonformal and experiential learning), and questions relating to how an elevated civic science literacy among adult participants may be asserted by the participants in social forums and within a scientifically evolving democracy. Questions were designed to avoid “yes” and “no” responses, except when appropriate, and to probe into how meaning structures and scientific generalizations emerged from participation. In addition, the questions collectively answered how nonformal outdoor adult education, as a major component of the renewed citizen science paradigm, affected the participant’s level of civic science literacy and how such elevated civic science literacy, couple with the personal experiences of participants in citizen science programming, may have developed into increased participation and personal assertion in social forums within a scientifically evolving democracy.

As responses to the structured interview questions were recorded, the wording of unstructured, open-ended questions were completed. This technique allowed the participant to focus on their memories and personal feelings in giving responses to questions relevant to their personal and renewed citizen science paradigm experiences, while allowing the researcher to incorporate the participant’s vocabulary, field experience context, and citizen science research data from their structured interviews into the
wording of the unstructured interview questions. With data collection and analysis occurring concurrently during the course of the research, the researcher was able to make adjustments to the guiding framework and, as stated by Merriam (2002, p. 14), “test emerging concepts, themes, and categories against subsequent data.” The rigor of this procedure, analytical induction, leads to an understanding of the phenomenon within the confines of the phenomenon’s context and position in time (Robinson, 1951). This procedure insured the clarity of the questions being presented to the participants.

Immediately following the interview, the handwritten transcript was presented to the participant for their review. Participants were asked to comment on the validity of their responses. Member checks, as the procedure is referred to, states Merriam (2002, p. 26), is a “common strategy for ensuring validity in qualitative research.” The process was also conceived as a method for improving researcher-participant relations throughout the course of the interview process. By making the member checks procedure explicit to participants prior to the interview, the participants felt more comfortable to speak freely knowing they were being provided an opportunity to review their responses and clarify, states Merriam (2002), “whether your [the researchers] interpretations ‘ring-true’” (p. 26).

3.5 Data Analysis

3.5.1 Quantitative Methods

The survey instrument employs a “Before Research” and “After Research” four-point Likert scale designed to enable the participants to self-report their scientific vocabulary knowledge and science process understanding, both prior to and following their participation in the 2010 RRBSA. The Likert scale provides the participant a defined
continuum that helps to prevent participants from making judgment calls on their self-defined conceptions of civic science literacy. In addition, the Likert scale was designed to lend clarity to the self-reporting measure and, as previously discussed, not for the application of statistical analyzes that weigh the numeric value of each item along an interval scale.

In preparing the surveys for statistical analysis, surveys are re-scored using a dichotomous scheme in which all responses of “0,” “1,” and “2” are recoded to “0,” and all responses of “3” are recoded to “1.” This dichotomous construct is conceived to capture only responses that indicate full achievement in civic science literacy, as defined within this research, among line items. Similarly, all other responses on the survey, everything from “0” to “2,” is recoded to “0” to clearly indicate that civic science literacy has not been achieved; even if marked improvements have been self-reported as a result of the volunteer’s participation in the RRBSA research. After dichotomous coding, the summation of civic science literacy relevant line items both before and after the 2010 RRBSA for each participant was imported into SPSS as an aggregate value; resulting in an interval scale for statistical analysis.

In testing the statistical gains in civic science literacy as a result of the 2010 RRBSA while conducting citizen science research, and given the dependent nature of the data, a paired t test was performed. Paired t tests have greater power than unpaired t tests particularly given that the confounding factor of “noise effects” is assumed to be similar in the before research (μ₁) distribution as the after research (μ₂) distribution since the participant pool is unchanged (David & Gunnink, 1997).
The null hypotheses were tested using International Business Machines (IBM) SPSS 19.0 for Windows (© 2010) software. SPSS imported a Microsoft Excel spreadsheet containing the data and calculated the student t score. The t score was compared against a one-tail t distribution based on 14 (n=15) degrees of freedom using the conventional significance value of 0.05 (α=0.05), which corresponds to a probability of less than or equal to 5% (P≤0.05) of making a Type I error that would erroneously reject the null hypothesis when, in fact, it was true. Although a significance value of 0.05 is widely accepted in statistical analysis, the data was also evaluated at the scrutiny α=0.01 (P≤0.01). A t score larger than its corresponding critical value (t score) represent a statistically significant difference in the civic science literacy of participants after research compared to their level of civic science literacy before research (Howell, 2002; Fraas, 1983).

3.5.2 Qualitative Methods

Data analysis of interview responses, as Merriam (2002) reminds us, “is an inductive strategy. One begins with a unit of data and compares it to another unit of data, and so on, all the while looking for common patterns across the data” (p. 14). Towards developing coding schemes and recognizing emerging patterns, completed, hand-written interview transcripts were placed into an electronic format; verbatim. Each participant was assigned a pseudonym and all responses were numbered and electronically formatted to assist in analysis.

Basic interpretations relevant to self-report survey and interviews, as previously discussed, are taken as valid and reliable responses. According to Giddens (as cited in Kemmis & McTaggart, 2000, p. 573), participants in social settings are not “cultural
dopes.” Kemmis and McTaggart support this notion by stating that participants, “can give cogent reasons for their intentions and actions, and generally demonstrate a sophisticated understanding of the situations they inhabit” (p. 573). While the answers are accepted as valid, each interview transcript was reviewed several times to develop an increased understanding of the participant’s experience, knowledge development, and perspectives related to their civic science literacy both in the present and the past. In unison with the suggestions of Bogdan and Biklen (2007), transcripts were reviewed for regularities and patterns pertinent to the research problem and research questions. Common themes were then coded using an alpha-numeric scheme designed to lend clarity to the underlying motivation, initial civic science literacy, level of civic science literacy following programming, and how such knowledge may be utilized in both personal and social forums requiring some level of civic science literacy for competent participation. The coding scheme was intended to be clear, aid the researcher in answering the research questions, and provide suitable understanding given the constraints experienced during the research process.

Following a thorough reading of the transcript by the participant, the participant data was collated as an Excel spreadsheet and organized in a manner so that all participant responses to similar questions were grouped together. Viewing all participant responses to the same question allowed the researcher to identify common threads across question responses. This methodological decision also enabled the researcher to identify broad structural codes (within the chronology leading up to and following participation in citizen science programming) that may, or may not, have been identified during the transcript reviews. The electronic formatting also facilitated and enabled clear
communication throughout the peer review process. Peer review is a purposeful method in which the researcher asks a colleague to review the data and, “assess whether the findings are plausible based on the data,” states Merriam (2002, p. 26). The procedure serves as a method for confirming the interpretation of data and increases the reliability of research conclusions (Merriam, 2002). While initially conceived to occur following the researcher’s alphanumeric coding and identification of common threads across participant responses, time considerations were discussed among faculty and this phase of the research methods was agreed to be omitted after the coding scheme was reviewed. To compensate for this decision, the researcher did meet with a representative from both the facilitating and sponsoring organization to discuss common themes and threads unveiled in the analysis. Each representative, as an outside informant without a stake in the research, confirmed the generalizations and overarching themes unveiled in the data.

Each interview analysis began with the identification of the underlying reason the participant identified as why they chose to participate in the RRBSA, and as such, whether explicitly known to the participant or not, chose to participate in a volunteer activity capable of elevating the civic science literacy of participants. The coding was expected to result in two broad situation codes, those related to an elevation in civic science literacy and those related to the assertion of civic science literacy, but two additional situation codes emerged during analytical induction. These two codes, motivation and experiential participation, were added to the coding scheme due to both their salience in leading to elevations in civic science literacy and the importance assigned to them by the participants themselves. These four “signs,” as the categories are termed by Bogdan and Biklen (2007, p. 173), were then subdivided to reveal common
themes (additional coding categories) associated with each sign. For example, civic science literacy, as a situation code, was subdivided to include two process codes (science vocabulary knowledge and science process understanding) for scrutiny as the situation code began to delineate itself across responses.

The final coding stage incorporated event codes with process codes to relate, according to Bogdan and Biklen (2007, p. 177), “specific activities that occur in the setting or in the lives of the subjects you are interviewing.” The event codes are intended to direct the researcher towards the happenings that are key in participant decisions, a relevant methodological construct for assessing any elevation in the civic science literacy and assertion of civic science literacy in social forums within a scientifically evolving democracy. The coding scheme has been included as an appendix (Appendix A).

3.6 Institutional Review Board

Prior to beginning this research, an Application for Project Review was submitted to the Cleveland State University Institutional Review Board (IRB) for Human Subjects in Research. The board reviewed all materials relevant to the research, including the purpose of the research, the consent form, a statement of potential risks, and an overview of the anticipated participants. With approval from the IRB, data collection was approved to commence in accord with the approval date from the IRB. All participants were required to read, discuss, and agree to the terms included and specified on the IRB approved consent form. Participants were assured their confidentiality throughout the research process (all names appearing in the final research and any manuscripts/publications will be pseudonyms), and informed that they would neither be compensated nor required to participate. Their participation in this research was
completely voluntary. All data records are electronically stored in a double-lock safe where they will remain for a period of three years, as required by federal law, before being permanently destroyed or retained in confidence under the auspices of the preceding protocols.

3.7 **Researcher-Interviewer**

The researcher-interviewer for this work is a European-American male with a bachelor’s degree in geological sciences and a master’s of science in environmental science with a geochemistry concentration. I am currently a candidate for a doctorate of philosophy degree in urban education: leadership and lifelong learning. I am interested in, and have previously conducted research in, the role of non-classroom settings and, as coined by Caulton (as cited in Hall & Bannon, 2006, p. 231), “edutainment.” As an academician, I support the science-based foundation of citizen science programming but firmly believes in utilizing the forum towards developing methods of improved knowledge transmission and discovering how a renewed citizen science paradigm can be expanded to meet an expanding audience of science-seeking adults while maintaining the academic and professional pursuits of the sponsoring organizations that make citizen science programming possible. Prior to engaging in the research, I completed on-line coursework in Human Research Curriculum through the Collaborative Institutional Training Initiative (CITI) at the University of Miami to renew his biennial certification.

3.8 **Researcher Bias**

As an experienced quantitative researcher, tackling qualitative research was an intimidating, yet exciting proposition. While I would have been more comfortable with an exclusively quantitative methodology, an unbiased assessment of the research
questions and a best approach analysis for elucidating robust data results quickly enriched me to the value of qualitative methods. Qualitative research can be fraught with researcher bias, a situation in which the accuracy of collected data and sweeping conclusions may be severely compromised. Towards evading the potential of subjectively derived research data and conclusions, it is important for researchers to understand their own assumptions, beliefs, and behaviors that envelop the potential to steer the researcher towards personally desirable conclusions (Bogdan & Biklen, 2007).

The most prevalent form of researcher bias, state Brott and Myers (2002), is “the possible selection of participants by the researcher to reflect preexisting biases and perceptions, and the unique perception and experiences of the [participants] that would lead them to respond in particular ways to the research questions” (p. 147). To avoid falling into this qualitative research pitfall of great frequency, the research is being executed with participants from a preexisting citizen science program sponsored and executed by an outside agency; not a program developed and/or executed by the researcher. All participants will be congregated by the facilitating agency for the collection of specific types of data predetermined by the sponsoring agency. In addition, the participants will not be apprised of the research until the end of the program and will have been required to have participated in all nonformal outdoor adult education sessions. This established criterion will be dictated by the participant’s individual schedules and motivation; factors completely out of the researcher’s hands.

Researcher bias will also be avoided within the research data collection portion through the use of structured interview questions. Each question is designed to be clear, non-leading, and intended to solicit a response that would be unaffected by both my
presence and personal beliefs regarding the civic science literacy of the participants.

Further considerations are made during the second phase of the research through the use of unstructured, open-ended interview questions. Each question specifically addresses a theme or participant response during the structured interview phase, and whenever possible, the vocabulary and locution of the participant will be used in formulating the questions. This procedural aspect insures that the participants fully comprehend the question being asked and that responses are not abridged to avoid a potential miscommunication.

An additional, purposeful consideration will be taken in respect towards the development of coding categories. The nature of structured interview methods allows situation codes and process codes to be hypothesized before the start of the research. While the situation codes, and some process codes, may be designated \textit{a priori}, many of the process codes and all event codes cannot be designated \textit{a priori} without channeling researcher bias into the results. This decision to denote some codes while waiting for others to emerge is intended to avoid a coding scheme that results from a convergence of participant responses and researcher bias, as may be potentially manifested during the unstructured interview phase.

Qualitative researchers, states Clifford (as cited in Fine, Weis, Weseen, & Wong, 2000) tend to view their subjects with “alluring fictions” (p. 117). In spite of our best intentions and attention to detail, the literature would have readers believe that qualitative researchers view their participants and data with subjectivities, assumptions that support intended findings, selective attention, selective interpretations, conclusions derived from bias, etc. (Bogdan & Biklen, 2007; Fine, Weis, Weseen, & Wong, 2000; Tisdell, 2002;
Brott & Myers, 2002). Even when one believes they are functioning armed with an elevated notion of responsibility in research, “in spite of best attempts to do otherwise,” states Tisdell (2002), “we tend unconsciously to project our own experiences or knowledge onto others stories” (p. 90). The critiques and evaluations are never well received, but an ostensible reality when one veers from a strict code of ethics in the conception, execution, and conclusions of qualitative research. This research embraces the most stringent code of ethics, the constructs of the Belmont Report, and objectivity in the study of the subjective. In addition, the integrity of the research and any bias the researcher may hold, will be policed through members check and peer review procedures.

3.9 Limitations of the Study

3.9.1 Relations with the Facilitating Agency

Every program planning process has a starting point, and for this piece of research, it is acknowledged that the starting point is unique and needs to be planned independent of preexisting protocols (Sork, 2000; Caffarella, 2002; Cervero & Wilson, 2006). Given the dynamic nature of program planning across space and time, coupled with the ever-changing face of the “planning table,” isolating an idyllic theory for guiding the program planning process is an impossible venture. Reverting to more simplistic guidelines, a program that successfully meets its program and research objectives is a reflection of a good program plan. While I do not know if my plan will lead to such success, I have matriculated throughout the planning process by identifying all parties with an interest or potential interest in the program and research, developed a working relationship with those parties, and have both formulated and expressed my research objectives in a manner that they are “written clearly enough so they can be understood by all parties
involved,” as advised by Caffarella (2002, p. 370). Forester (1989) points to information as one of the most important attributes of power, both accurate information and misinformation, and how such information is expressed, heard, and believed.

For all research plans involving outside parties, all of whom hold more power than myself in determining the success of this research, I have applied Ralph Tyler’s (2004) Basic Principles of Curriculum and Instruction. The 1949 theory prescribed a linear, step-wise process to planning, dubbed the “Tyler Rationale” (Sork, 2000, p. 171), encompassing four questions addressing the purpose, content, method, and evaluation of the research. While many have contested whether Tyler’s theory is in fact an adult program planning theory at all, Sork (2000) noted that when “reworded in a variety of ways – [Tyler’s theory] provided an attractive framework used by others to produce models suitable for adult education” (p. 172).

3.9.2 Attrition

A second limitation emblazoned in the study is the possibility of inadequate data due to participant attrition. Clearly understanding the participation of volunteers traditionally wanes with time, either due to program-centric factors or unforeseen life circumstances, citizen science program planners have always depended on a large, initial pool of volunteers to insure adequate data at the program’s end. This research is centered on a temporally and spatially controlled citizen science program planned and facilitated in conjunction with an outside agency, which may or may not meet the needs of the participants. Towards developing methods that minimize attrition, this research recognizes and addresses the two types of participant attrition: treatment attrition and
pretreatment attrition (Hofmann, Barlow, Papp, Detweiler, Ray, Shear, Woods, & Gorman, 1998).

Treatment attrition is the loss of participants during the course of the research, whereas pretreatment attrition is primarily centered upon a participant’s unwillingness to participate in the research aspect of the program (Hofmann et al., 1998). Although it is understood that, “Attempts to reduce attrition are not always met with complete success,” state Ribisl, Walton, Mowbray, Luke, Davidson, and Bootsmiller (1996, p. 1), treatment attrition may be avoided during the course of this research through the study of more spatially or temporally controlled citizen science programs. Such programs are hypothesized to have minimal treatment attrition due to the personal relationships developed among participants during the course of the program. In addition, by focusing on programs with limited duration, the chance of participants moving, experiencing a change in daily routine, becoming pregnant, passing away during the research, etc. can be minimized.

Pretreatment attrition is more challenging to minimize as the type and duration of a program plays a minor role, if any role at all. Many volunteers are willing to volunteer in various programs but become disfranchised when they learn that they will be asked to participate in a second area of research; sometimes feeling tricked or fooled into the secondary research (Hofmann et al., 1998). To minimize pretreatment attrition, no mention of the parallel research occurring both during and following the program was mentioned.
3.9.3 Generalization

Much of the critique of academic literature lies in researcher’s claims of generalizability. Far too often, researchers attempt to take their research results and make claims of widespread applicability across space and time. “When researchers use the term generalizability,” elaborates Bogdan and Biklen (2007), “they usually are referring to whether the findings of a particular study hold up beyond the specific research subject and the setting involved” (p. 36). The fundamental question is to what extent can the findings of one piece of research be applied to additional situations? This research has a priori notions of generalizability - generalizability reflecting a particular context (citizen science programs) with situation-specific factors (a renewed citizen science paradigm incorporating nonformal outdoor adult education) from an alternative perspective of what generalizability can truly mean (Merriam, 2002).

Due to the architectural framework of the research, as is the case with all analytical induction, “the claim to universality of the causal generalization is the weakest,” state Vidich and Lyman (2000, p. 57; italicized for emphasis). However, generalizability can be approached from an alternative stance. According to Merriam (2002), “what we learn in a particular situation we can transfer to similar situations subsequently encountered” (p. 28), deeming a successful research methodology as generalizable as a prototype, not as a result. With small, nonrandom samples specifically designed to lend deeper understanding to the research questions, this research attempts to be both as descriptive and informative as possible for situation transfer. In addition, this research was designed to research a minimum of two citizen science programs. A multisite design provides “maximizing variation” towards a more generalizable prototype for a greater range of
citizen science program situations in the future (Merriam, 2002). Whereas this specific methodological consideration of multiple sites was not able to come to fruition in this research, the autonomy of volunteer groups at research reaches throughout the 2010 RRBSA effectively worked to produce a variant of multisite design.

3.9.4 Participation and Assertion of Civic Science Literacy

Since the United States Constitution was ratified and made operable on March 4th, 1789, the foundation of participation – including the assertion of civic science literacy - in democratic processes has always been divided into three discernable factions; each of which deserves some attention as it relates to this research. With no a priori knowledge of what faction each of the participants in this research resides, limitations are abound in formulating a path for the evaluation of assertion without making some assumptions. The data collection stage of this research may be severely limited through the assumption, derived from knowledge related to volunteerism and alignment with nonprofit organizations, that the participants are active participants in social and civic forums within a scientifically evolving democracy; members of the third faction.

The first faction consists of American citizens who are passive and allow the political processes to occur without any input. Many of these individuals are not registered voters and often do not participate in any number of political/policy circles, whether familial, local, state, or more broadly national. The resounding belief is “my vote doesn’t count” and/or “I’m just choosing between the lesser of two evils” (Irubin39, 2008).

The second faction consists of American citizens who are active in the process of electing officials who they feel will represent their best interest, only to become passive in policy circles; effectively only voting in mayoral, gubernatorial, and presidential
elections. In his 1919 speech at Princeton University to a group of undergraduate students, Henry H. Goddard vehemently supported this state of democratic affairs towards the evolution of a desirable social inequity. “Democracy,” stated Goddard (as cited in Gould, 1996, p. 191), “means that people rule by selecting the wisest, most intelligent and most human to tell them what to do to be happy. Thus democracy is a method for arriving at a truly benevolent aristocracy.”

The third faction consists of American citizens who are active in both the election and individual political/policy circles on a recurring basis; taking advantage of all the benefits of the Constitution afforded to them. Experiential learning is philosophically grounded in the work of John Dewey, who believed, first and foremost, the key to an effective democracy was an educated society. “A democratic society could exist and function well,” state Freeman, Nelson, and Taniguchi (2003) elaborating on the works of Dewey, “only if the citizenry was well-educated and contributing to society.”
CHAPTER IV
RESULTS

Among the three prevalent forms of science literacy, there is no doubt that civic science literacy is both in its infancy and the category that is the least pervasive among the general public (Miller, 1998). The most salient reason for this lack of civic science literacy is that the general populace, regardless of background or experience, has little to no knowledge of scientific vocabulary or science process understanding (Shen, 1975; Pool, 1991; Miller, 1998; Jenkins, 1999). The purpose of this research was to address the lack of civic science literacy of American adults in a scientifically and technologically evolving society by elevating their scientific vocabulary and science process understanding through an innovative curricular methodology.

This research hypothesized that the inclusion of nonformal outdoor adult education (NOAE) with experiential learning in citizen science programming – a conceived and developed renewed citizen science paradigm – can elevate the civic science literacy of American adults. Towards this end, this work addressed two central questions:

1. Can nonformal outdoor adult education incorporating experiential learning in a renewed citizen science paradigm improve the civic science literacy of adult participants?
2. To what extent can nonformal outdoor adult education incorporating experiential learning in a renewed citizen science paradigm that addresses and advances the civic science literacy of adult participants elevate the participation and assertion of volunteers in social forums and within a scientifically evolving democracy?

A mixed-methods approach incorporating self-report surveys and both structured and unstructured interviews, coupled with a thorough analysis of the data, revealed that not only did the renewed citizen science paradigm markedly increase the scientific vocabulary knowledge and science process understanding, collectively constituting civic science literacy, of participating adults, but, additionally, elevated their assertion of their recently acquired civic science literacy in social forums within a scientifically evolving democracy. Furthermore, the data revealed, unexpectedly to the researcher, that the time commitment necessary for such marked increases was far less than anticipated; a phenomena believed to have been facilitated by the team atmosphere and content discourse beyond the direct commitments to the citizen science program itself.

4.1 The 2010 RRBSA Citizen Science Program

Whereas it was known to this researcher that involvement in a preexisting citizen science program would be accommodated, the exact details of the program and how the renewed citizen science paradigm would unfold and adjust to the ever-changing temporal dynamics of the program was unknown a priori. Due to the program’s evolution and execution – methodological information that could not be known in advance – the following narrative of the program semantics and execution observed throughout the RRBSA is appropriately included as a result.
The Biomonitoring Stream Assessment (RRBSA) citizen science program has been executed by the sponsoring agency each of the past twelve years; on a stream from this point forward referred to by the pseudonym Research River. As an important tributary to Lake Erie, and an urban stream system with nearly 30 river miles winding through the centuries-old infrastructure of an urban metropolis and its surrounding suburbs, several state and local agencies astutely monitor all aspects of the Research River on a regular basis. With several other large stream effluents entering the Lake Erie system in the region, the necessary resources and human capital to perform chemical and/or biological stream assessments on the Research River are not available. Several agencies rely on ancillary data received through remotely transmitting data stations, but, more importantly, they rely on the general public to alert them when something about the system begins to change. For example, the Research River is a prolific spawning ground for the steelhead trout that spend their summer months in Lake Erie; a phenomenon that draws hundreds – if not thousands – of local fishermen and fisherwomen to the stream system every year. For those who spend several days a week in the stream system fishing, many agencies rely on them to report any observations of change within and surrounding the system, no matter how minor. After all, who knows more about the particulars of a system reach, regardless of academic or scientific background, than someone who spends several days a week at that location? Their efforts have helped map the dispersion of the invasive lamprey eels and streamside fauna, remediate storm water effluent infrastructure damage, and locate specific locations of fish habitat, among other contributions. While fishermen and fisherwomen have served a valuable role in alerting state and local agencies of system changes, it still takes a large team of people to study,
monitor, and remediate the exact problems affecting the Research River over tens of river miles; many of which do not have public access points. Towards this end, several citizen science programs have been instituted over the past two decades to address the lack of human and financial capital needed to properly study and monitor critical aspects of the stream system. One of these programs, the Research River Biomonitoring Stream Assessment (RRBSA), was developed and made operational in 1998.

This research is a mixed-methods investigation of adult participants who freely volunteered and fully participated in the 2010 RRBSA citizen science program. In previous years, the RRBSA was executed in a manner congruent with other citizen science programs. Among these antiquated protocols was volunteer recruitment only among existing volunteers with the facilitating agency, a brief orientation to collect personal information for liability and legal purposes, and an informational pamphlet from the Ohio Department of Natural Resources (ODNR) distributed along with Stream Quality Management Assessment (SQMA) data sheets. Volunteers would leave the orientation with no other obligations and it was hoped they could work autonomously to educate themselves and collect data for the sponsoring organization. The totality of the contact between volunteers and any agency involved in the research would typically, as I was told by one of the naturalists, “rarely exceed an hour or so for the summer.” In their most successful year, 2003, seven volunteers collected approximately 200 pieces of data and, one naturalist shared with me, “the data was insignificant and not even submitted to the sponsoring agency. A lot of times, I think most people are just guessing.”

The preexisting annual RRBSA citizen science program was redesigned, andragogically, to include nonformal outdoor adult education (NOAE) and enhanced
experiential learning following James Coleman’s (1976) framework – the renewed citizen science paradigm – and was executed following the time constraint (June 15th to October 15th, 2010) and guidelines set forth by ODNR’s SQMA protocols (Appendix B). Volunteer solicitation was performed through print, electronic media, and word-of-mouth program introduction to both volunteers from previous years and local citizens with an expressed interest in participating. While this research focuses solely on the adult participants, those empowered by virtue of their age to participate in democratic processes governed by the United States Constitution, no age, physical, or other restrictions were imposed on who among the general citizenry could participate. All interested parties were welcomed. In total, 67 individuals volunteered to participate in the 2010 RRBSA employing the renewed citizen science paradigm.

4.1.1 The RRBSA: A Renewed Citizen Science Paradigm

In redesigning the citizen science paradigm, a NOAE component was incorporated. The RRBSA kicked off with a face-to-face orientation session held on June 13th at a local nature center within one of the many protected, natural land reservations that emotionally and spiritually claim some stretch of the Research River as their own. Thirty-three volunteers (26 adults and six children) attended the kick-off event and the NOAE-based orientation began with an introduction of the research purpose and the agencies involved in, or with an interest in, the data collection. The first of the two one-hour sessions was held in an open part of the nature center where park visitors, and often their pets, were commingling or simply stopping by to listen to the naturalist’s introduction and review of the SQMA protocols. The decision to execute this aspect of the orientation session in an open, public area was to insure the comfort of the participants, following andragogical
constructs, and to entice, and perhaps recruit, additional volunteers among the general public who stopped to listen and/or asked about what was taking place.

A naturalist from the facilitating agency led a thorough discussion – not a lecture – with the participants on each of the items on the SQMA data sheet. Each term was discussed within a narrative with the group and questions were fielded as they arose (opposed to asking volunteers to hold their questions until the end). Prior to beginning the discussion on aquatic macroinvertebrates, the naturalist revealed hundreds of lucite-encased specimens preserved for scientific purposes. This aspect of the orientation provided each of the volunteers an opportunity to see and examine the physical characteristics of aquatic macroinvertebrates and other insects they might encounter in the field (a marked difference in honing identification skills compared to traditional PowerPoint slides or an image-laced brochure). In addition to discussing all the scientific vocabulary and collection aspects of the SQMA data sheet, the naturalist made careful considerations in creating mental images and guided imagery to provide the volunteers with a sense of the experiential learning they would engage in. While much of this imagery was to insure the personal safety of the volunteers while in the field, the remainder taught volunteers about acting on their environment, noting how the system changes from research collection period to research collection period, and those variables that should be looked for that one would typically not associate with biomonitoring and/or not think the presence or absence of was of importance. Volunteer information, including contact information, was collected at the end of the event at the nature center for continued communication throughout the RRBSA.
The second one hour session of the NOAE-based orientation found the volunteers immersed in the environment of study and provided with a tutorial and mentorship for many of the actions they would be making throughout the course of the research. This is a critical aspect of enhancing experiential learning; it needs to be taught while immersed and not assumed to be either an intrinsic skill the volunteer brings to the program or one that the volunteer can execute in context following informal education. The volunteers gathered at a local picnic area along one of the stream reaches included in the research; just one-half mile south of the nature center and well within walking distance. Volunteers were shown how to properly use many pieces of equipment – including a seine, global positioning systems, and a variety of tools and implements for collecting individual specimens without harming them. Volunteers were also introduced to SQMA protocol actions such as properly performing assessments of the stream substrate, identifying bedgrowths, gauging turbidity, and a variety of other scientific procedures. Each volunteer was offered an opportunity to use each piece of equipment and perform every assessment called for in the SQMA while having a naturalist and/or aquatic entomologist mentoring them and answering any questions. The streamside session concluded with an actual collection of aquatic macroinvertebrates, streamside insects, and fish to not only demonstrate the SQMA process in its totality, but to give each volunteer an opportunity to examine real specimens, fine tune their identification skills, and ask questions in which the answers had contextual applicability in guiding experiential learning.

At the end of the orientation session, volunteers were treated to a cookout next to the stream. The cookout was a purposeful construct to facilitate the development of a team
atmosphere among volunteers; volunteers were also given the opportunity, in advance, to invite their family. It was known that the inclusion of a cookout may normally exceed the time commitment volunteers would normally make, but by inviting their family and friends – as well as executing an entertaining, educational program that would keep their enthusiasm and interest high – we felt the cookout would be a success. Although no R.S.V.P. was required for the cookout (we did not want to make the volunteers uncomfortable or feel trapped by an obligation), all but one of the volunteers stayed for dinner and seven additional volunteer family members came to enjoy the evening in the park. While the food and music was not very good (the director of the facilitating agency asked me if I would attend to the grill and the music during the event), the cookout was an overwhelming success in meeting its goals. Volunteers who had just met for the first time began making plans to go out in the field together and a team efficacy was emerging among volunteers, including those volunteers who had just met each other for the first time that day.

Following the orientation, the volunteers were e-mailed to thank them for their decision to participate and to remind them that their first biomonitoring stream assessment should take place between June 15\textsuperscript{th} and July 15\textsuperscript{th}. Without pause, volunteers began checking out equipment provided by the facilitating agency (equipment that was decided to be stored at the nature center due to the volunteer’s knowledge of its location) and turning in completed SQMA data sheets to the naturalists at the facilitating agency. While volunteers were apprised of the 15 reaches that had been designated by the sponsoring agency for biomonitoring stream assessment, no specific assignments had been made. This allowed volunteers to choose the reach that was most convenient and/or
most comfortable for them, and hopefully result in duplicate biomonitoring stream assessments; something the sponsoring agency hoped for towards checking data validity. Surprisingly, after one-month’s time, every reach had been assessed at least once and many had been duplicated.

In response to the first e-mail, many of the volunteers took the initiative to stay in touch with the facilitating agency. Many volunteers, as a result of one of the targeted goals of the first NOAE session and cookout, had already become so comfortable with the program, its importance, and the individuals involved, that they stayed in e-mail contact with the naturalists, the aquatic entomologist, and the researcher. This contact, coupled with the willingness of the facilitating agency, resulted in many of the new volunteers being joined in the field by a facilitating agency mentor to help them during the first collection cycle. This second form of NOAE - mentorship in the field and the emergence of members of the scientific community with the general citizenry - as discussed by many of the interview participants, was so important in building their confidence to execute the research, crystallize the scientific vocabulary in context, and begin to understand how to navigate the framework of experiential learning towards science process understanding.

After the first biomonitoring stream assessment cycle was completed for each of the fifteen reaches, the volume of data, along with initial word regarding the validity of the data by the sponsoring agency, was unprecedented compared to any previous RRBSA citizen science program executed in the past. Many of the state and local agencies who held an interest in the data, including the sponsoring agency and an affiliated institution, voiced interest to the reservation director about meeting the volunteers. In cooperation
with the reservation director and the researcher, it was decided – given the success of the first cookout – to have a second streamside cookout for the volunteers. The second cookout would not only provide an opportunity for volunteers to convene as a team, continue building an efficacious atmosphere, and commingle with the many scientists involved, it provided an opportunity to execute a second NOAE session exactly where the volunteers were most comfortable – in the outdoors.

The second streamside cookout took place on July 18th. For the NOAE session, the director of natural resources and aquatic research director from the sponsoring agency, an aquatic entomologist from an affiliated institution, and a naturalist from the facilitating agency were all in attendance. The goal was to allow those individuals most vested in the data to share with the volunteers the successful nature of their efforts, the validity of the data submitted, reassurance of their abilities, and to continue fostering a team atmosphere. The director of the sponsoring agency led the NOAE session and facilitated a discussion with volunteers while sitting on a picnic table, wearing camouflage pants and a ripped blue t-shirt, and feeding his 120lb bear of a dog hamburgers (many volunteers later shared with me how their stereotype of scientists was shattered). The director of the sponsoring agency discussed the value of the volunteer’s data and the potential for the 2010 RRBSA data in making “real dents” in the scientific understanding of the Research River stream system. Through his purposeful use of the scientific vocabulary related to the SQMA and the first NOAE session, he worked to reinforce the civic science literacy gains the volunteers were making while discussing the more broadly political nature of the data and its use in a scientifically evolving democracy.

The director of the sponsoring agency concluded the NOAE session by encouraging the
volunteers to continue their great work, providing the volunteers with his contact information, and pledging both his time and the time of his agency whenever needed. He then spent the remainder of the evening (over three hours) speaking with each volunteer individually; a seminal part of the RRBSA that every participant in this research told me was key in affirming to themselves their value in the research and making real contributions; the feeling of being a scientist.

Without asking the volunteers to R.S.V.P., it was believed that this second NOAE session would be highly attended due to the participation of the volunteers and the agency scientists who committed to attend. What was not expected was the number of friends, family, and new volunteer recruits that had been invited by the volunteers to accompany them; a phenomenon catalyzed by their discussions and shared experiences of their RRBSA research. Forty-two volunteers, 31 established volunteers and 11 new volunteers, and 13 family members attended the event. The volunteers, including those who did not know each other prior to the program, continued building new relationships and facilitated an increasingly efficacious team. Before the second NOAE session was even complete, it was already understood that something very special was happening. The naturalist told me later that the participation and retention of volunteers had already exceeded any citizen science program previously executed by the facilitating agency. Her exact words at one point were, “even if the program ended today we would already have more data than we have ever collected in any year before” (personal correspondence, July 20, 2008).

The second NOAE session revealed a bit of a problem from a planning and logistics standpoint. The sponsoring and facilitating agency had been running this program for
over ten years, but never with such a large, dedicated group of volunteers. The amount of equipment, data sheets, petty cash, and other resources was only designed to accommodate a group of about six to ten citizen science volunteers; with anticipated attrition after the first collection cycle drawing the number of volunteers down to about four to six. The 2010 RRBSA began with 42 volunteers (33 of whom attended the NOAE orientation session) and had now, instead of experiencing attrition, grown to 59 within one month’s time. With the joint effort and program planning relationship that had grown between the researcher, the facilitating agency, and the sponsoring agency, the researcher would unexpectedly become more responsible for managing several facets of the RRBSA. After all, the renewed citizen science paradigm and the success of its execution, while pleasantly unexpected by the agencies involved, was the researcher’s idea!

Continued e-mail correspondence was maintained with the volunteers for the next two months; a job the naturalist and reservation director asked me to assume and which I accepted. Volunteers were e-mailed approximately twice a month, once prior to each collection cycle as a reminder and once following each collection cycle to personally thank the volunteers and encourage discourse about their experience. To my surprise, not only did the volunteers e-mail me, but they began to e-mail each other (including me as a cc) and collectively organizing themselves to visit new reaches, go out in the field with other teams, and even meet outside of the program at various local establishments. The relationships and team efforts that developed throughout the RRBSA citizen science program not only led to greater organization among the volunteers in the use of equipment (scheduling around each other’s schedules), but an increased, more veracious
data set resulting from additional reach SQMAs and larger, self-constructed, teams of volunteers cross-checking and confirming each other’s data and experiential observation hypotheses. In short, the volunteers became their own citizen science program facilitators and kept their own checks-and-balances to insure all the reaches were completed on time and with both the highest level of validity and the greatest respect for the environment. Surprisingly, the job of the facilitating agency and the researcher began to wane as the volunteers themselves, now acting as a more cohesive unit than ever, took more ownership and responsibility for the RRBSA’s execution and data.

As the end of summer neared, the number of data sheets returned to the facilitating agency began to decrease. This turn of events was not a surprise to the facilitating agency, the reservation director, or the sponsoring agency as it was in accord with previous years. With the start of school and the responsibilities of both the parents of students and students themselves increasing, time was becoming scarce for the volunteers. Additionally, the stream reaches and the environment was becoming less hospitable than during the summer months – the water was cooler, the stream was inundated with leaf litter and organic debris, the paths and embankments had turned to mud, and the wind made for chilly conditions. With the conditions, although not favorable, still hospitable and safe for stream immersion and biomonitoring, it was important to execute a third NOAE session. While a third NOAE session was going to take place much sooner than anticipated, it was decided that the NOAE session would provide support and encouragement towards a final push for the October 15th deadline.

Whereas the streamside cookouts had been successful during the summer, the wet, wind, and chill of early autumn was sure to result in low attendance. The naturalists,
reservation director, and the researcher decided to plan an indoor event to be held in the assembly hall at the nature center, a location that all the volunteers were familiar and comfortable with. Although the budget had been all but depleted, we decided an inexpensive, fall-themed meal including sloppy joes and hot apple cider would encourage attendance. As always, the friends and family of volunteers were invited.

The third NOAE session took place on September 26th. While it was important to the naturalists, the reservation director, and myself to keep the event as nonformal as possible, it was also necessary to take some control of the session to share collected data, show preliminary statistical results, and discuss how the data may be used (elements intended to answer recurring questions from the volunteers). To facilitate a nonformal atmosphere indoors, round tables were set up, instead of ordered chairs similar to a classroom, and the volunteers, unannounced to them, would become the session facilitators (although no one was forced to participate). The aquatic entomologist, along with the assistance of the researcher under the tutelage of the reservation director, developed and presented a PowerPoint presentation. The presentation methodically started at river mile 0 and took the volunteers on a visual trip upstream, stopping at each of the 15 reaches included in the RRBSA. At each reach in the presentation, the aquatic entomologist discussed select aspects of the data, the unique aquatic macroinvertebrates identified, and why those organisms have taken a sedentary existence in that reach habitat; facilitating further science process understanding. The researcher than acknowledge those volunteers who had collected data at the reach and solicited the participation of the volunteers in leading a discourse to share their knowledge and experiences at the reach.
Forty-four volunteers attended the event, including four new volunteers who had been recruited by volunteers following the second NOAE session. The volunteers were happy to participate in the discourse and provided a tremendous amount of information on the system dynamics, educated the aquatic entomologist of finer details related to the aquatic macroinvertebrate habitat and system changes beyond the SQMA protocols. Volunteers professionally fielded questions from other volunteers in attendance and, elating the researcher, used the proper scientific vocabulary and science process understanding in answering those questions. The participation of volunteers as discussion leaders was well-received by the other volunteers and exceeded all anticipations; allowing the researcher to take a backseat and become educated as well. Following the NOAE session, a buffet style dinner took place and the volunteers spent nearly four hours (including two hours after the nature center had closed) discussing their experiences and making plans to execute biomonitoring stream assessments in the coming weeks before the program’s end. By the October 15th deadline, all 15 reaches had been visited one last time by volunteers and a complete data set for the year was finalized.

4.1.2 RRBSA Citizen Science Program Research Data

Over a period of four months from June 15th to October 15th, 2010, the RRBSA volunteers, working in teams of two or more, made over 100 reach visits (23 river miles) and collected over 30,000 pieces of data. Of prime importance to the sponsoring agency, facilitating agency, and the reservation director was the unprecedented identification of over 20,104 aquatic macroinvertebrates taxonomically to order. All data was assessed for validity by the sponsoring agency’s aquatic research coordinator, the sponsoring agency’s director - an aquatic biologist – as well as a team of additional natural science
researchers. The accumulation of data not only exceeded any traditional RRBSA citizen science program attempts executed in preceding years, but the data was found to have a high degree of internal and external validity; making the data, according to the sponsoring agency’s director, “admissible in a court of law, for the acquisition of easements, land management policy initiatives, and for the procurement of grants” (personal communication, October 27, 2010), among other actions that may be taken.

4.2 Data, Analysis, and Findings

Of the 67 volunteers, 57 were eighteen years-of-age or older, and 23 of those volunteers participated in all facets of the program, including the three NOAE sessions and the completion of each data collection cycle following the protocols set forth by the SQMA through the ODNR. As a result of their complete participation in the RRBSA program, these volunteers (n=23) became the central focus of the research phase and each was invited to participate in the research via verbal invitation. Each volunteer confirmed their affirmation to participate through the return of a signed consent form in which the purpose of the study and an outline of the research methods, including time commitment, was presented.

In the first phase of the research, self-report surveys (Appendix C) were mailed to each participant who signed and returned a consent form to participate in the research. The surveys were mailed to the participant’s address along with a self-addressed stamped envelope carrying the researcher’s address and the researcher’s university address as a return address. Participants were briefed in the survey instructions to omit any identifying information and to “complete the self-report, objectively and honestly on your own accord as time permits, and return all eight pages of the self-report in the self-
addressed stamped envelope provided. This construct allows the reports to be completed and returned with complete anonymity.” Of the 23 self-report surveys mailed, 13 were returned within one month’s time. To maximize the number of self-report surveys collected for this research, an e-mail reminder was delivered to each of the 23 participants who were mailed a self-report survey. Each of the participants was thanked for their time and consideration in their participation during this phase of the research, and for those who had not returned their survey, they were judiciously asked to do so. The following month resulted in the return of two additional self-report surveys.

Data collection involved two distinct phases, self-report surveys and interviews. Of 23 self-report surveys mailed following the protocols set forth in the methods, 15 self-report surveys (n=15) were returned and 10 participants (n=10) agreed to partake in the 120 minute interview (note: the 120 minute interview coupled with the additional time needed for members check exceeded any single individual time commitment required throughout the RRBSA). Several volunteers, while willing to participate in the interview process, could not make the time and/or accommodate their schedules in synchronicity with the researcher-interviewer.

4.2.1 Civic Science Literacy & Scientific Vocabulary Knowledge: Quantitative Results

Civic science literacy separates itself from practical science literacy and cultural science literacy in that the primary objective is the development of a society forged with the ability to make important scientific decisions regarding one’s life and to engage and participate in democratic processes centered upon science content (Shen, 1975). Any member of the general public who chooses to seriously engage in, or contest, any social or political issue with scientific dimensions must, at some point, learn the science related...
to the issue(s). Scientific knowledge must go beyond basic facts and trivia and encapsulate an array of science vocabulary and scientific process understanding.

Part one of the self-report survey specifically addressed the participant’s scientific knowledge on forty-one individual pieces of scientific vocabulary. Considering the importance of scientific vocabulary knowledge as one of the most fundamental attributes of civic science literacy, careful consideration was made as to the best measure to capture this data. Towards maximizing the validity of the research results related to scientific vocabulary, particularly in giving participants ample time to reflect on their learning, participants were mailed a survey instrument. The survey instrument employed a “Before Research” and “After Research” four-point Likert scale designed to enable the participants to self-report their scientific vocabulary knowledge, both prior to the RRBSA and following the RRBSA, along a defined continuum that helps to prevent participants from making judgment calls on their self-defined knowledge. From this construct, the Likert scale was designed to lend clarity to the self-reporting measure and not for the application of statistical analyzes that weigh the numeric values of each score along an interval scale. Returned surveys were re-scored using a dichotomous scheme in which all responses of “0,” “1,” and ”2” were recoded to “0,” and all responses of “3” were recoded to “1.” This dichotomous construct was conceived to capture only true scientific vocabulary knowledge by only counting “3,” “I can verbalize the definition of the term in a scientific manner,” as an indication of civic science literacy. Likewise, all other responses on the survey, including everything from “0,” ”I have no idea/I have never heard that term before,” to “2,” “I can verbalize what the term means, but not in a scientific manner and perhaps incorrectly,” is coded to clearly indicate that civic science
literacy was not achieved; even if marked improvements had been self-reported as a result of the volunteer’s participation in the 2010 RRBSA. The summation of the dichotomous data for each participant, both indicating acquiring civic science literacy and failure to acquire civic science literacy, was entered into an Excel spreadsheet. The spreadsheet was then imported into SPSS 19.0 for Windows for analysis.

Data regarding scientific vocabulary was collected from 15 participants for 41 different scientific terms introduced during NOAE sessions throughout the RRBSA. In testing the statistical gains in scientific vocabulary as a result of participation in RRBSA, a paired t test was performed. Paired t tests have greater power than unpaired t tests particularly given that the confounding factor of “noise effects” is assumed to be similar in the before research ($\mu_1$) distribution and the after research ($\mu_2$) distribution since the participant pool is unchanged (David & Gunnink, 1997). The null hypothesis is expressed as:

$$H_0: \mu_1 = \mu_2$$

or, equivalently:

$$H_0: \mu_1 - \mu_2 = 0$$

Statistical analysis was performed using SPSS 19.0 for Windows. The obtained t test score of the difference between the distribution of before research scientific vocabulary knowledge, $n(9.87, 9.45)$, and the distribution of after research scientific vocabulary knowledge, $n(20.53, 10.99)$, is 5.95. At a significance level of 0.05 ($\alpha=0.05$), the t critical value for a two-tail test is 2.145. Therefore, the null hypothesis ($t(14)=0.05 = 2.15$, $p<0.001$) has been rejected and it has been concluded that there is a statistically significant difference, at the 0.05 level (Table 1), between the participant’s knowledge of
### Descriptive Statistics

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### Paired Samples Statistics

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### Paired Samples Test

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**Table I. Science Vocabulary Knowledge Statistical Results.** SPSS 19.0 paired t test results for civic science literacy gains in science vocabulary knowledge.
scientific vocabulary before the research and the participant’s knowledge of scientific vocabulary after research. This result indicates that the participant’s knowledge of scientific vocabulary, by conventional criteria, is extremely statistically significant; indicating a marked elevation in the civic science literacy of participants as a result of participation throughout the RRBSA. Such results, given the uncommon usage of the scientific vocabulary on the self-report outside of the RRBSA, speak volumes for the effectiveness of increasing civic science literacy through the construct of an andragogically-based NOAE component within the renewed citizen science paradigm.

4.2.2 Civic Science Literacy & Scientific Vocabulary Knowledge: Qualitative Results

The second phase of data collection was the participant interviews. The interview consisted of both structured interview questions and unstructured interview questions. The structured interview questions are purposefully designed to be succinct, short-answer questions towards gaining knowledge on the participant’s background, their motivation for participation, their experiences throughout the course of the 2010 RRBSA, their personal feelings regarding the NOAE element, and to briefly assess their level of civic science literacy both prior to participation and following participation. The unstructured interview questions, roughly sketched as a series of incomplete questions designed to procure specific data through discourse, were executed during the open-ended structured format encouraging free speech among participants to capture key elements and elaborated responses extending from the structured interview phase.

Following the interviews all participants were provided with an immediate opportunity to read, and edit if necessary, their responses (members check). Upon completion of the tenth interview, a time when no further interviews could be or had been
scheduled to take place, an analysis of the data and the elucidation of common themes was performed. This methodological decision allowed general findings to begin to amalgamate into broad themes (situation codes) that permeated the research into more specific themes (process codes) and the events attached to them (event codes) (Appendix A). The situation code-process code of interest at this point of the research is an elevation of civic science literacy-science vocabulary knowledge.

Civic science literacy gains during the course of the 2010 RRBSA are believed to be a direct result of the NOAE component, a component that catalyzed and facilitated experiential learning. To substantiate this belief, participants were asked questions during the unstructured interview phase to draw out other possible modes of knowledge acquisition. For example, question F2 asked, “Talk to me about your time commitment to this program: Attending nonformal OAE [outdoor adult education]….Doing research on your own.” In addition, question J1 asked more pointedly, “Did you do any independent research during the program – either within the program (in the field) or away?” Such questions were designed to elucidate any ancillary research or informal adult education that took place among participants away from the RRBSA and determine if any gains in scientific vocabulary knowledge could be attributable to learning experiences not associated with the NOAE sessions of the RRBSA.

In evaluating questions F2 and J1, both the absence of other modes of education outside of the NOAE component and the validity of the participant’s responses emerged. For example, when asked if he did any research on his own (F2), Terry responded, “I did do some research on my own, just like looking at the dichotomous key before we went out, but nothing too extensive.” Similarly, when asked approximately one-half hour later
if he found himself doing any independent research during the program – either within the program or away (J1), Terry responded, “Nothing too independent… I would go over my identification skills and make sure I was prepared.” In this case, Terry showed consistency and internal validity in his responses – responding with similar answers to similar questions asked at different points during the interview process. In addition, Terry demonstrated scientific vocabulary knowledge gains in his use of the term “dichotomous key” during his response, a term that was presented at the NOAE-based orientation session and demonstrated for use for when participants entered the experiential learning phase.

Similar to Terry, Gerald presented both evidence of the internal validity of his responses and an elevation of civic science literacy through science vocabulary knowledge gained through NOAE sessions. When asked about doing research on his own (F2), Gerald responded, “…we went home and Googled water penny, and for that matter, we looked at a lot of macroinvertebrates to get other pictures and see how species looked.” When asked later if he found himself doing any independent research during the program – either within the program or away (J1), Gerald responded, “Not really, just looking up macroinvertebrates online. We also looked at the one insect book from the park but that was about it.” As with Terry and all the interview participants, Gerald voiced consistency in his responses – responding with similar answers to similar questions asked at different points during the interview process, and Gerald also demonstrated scientific vocabulary knowledge from NOAE sessions with the proper use of terms such as “macroinvertebrates,” and “water penny.” Although this aspect of the research data is not as exciting to discuss, its importance cannot be ignored. All of the
participants responded to questions J1 and F2 in a similar manner, demonstrating integrity in the interview process through their consistency in responses to similar questions. For the remaining eight interview participants, the trend continued but mainly with a resounding “no” to any form of independent research or other informal education outside of the NOAE sessions. Perhaps the majority theme related to the presence of other forms of education beyond the RRBSA NOAE sessions is best summed up by Jim who responded, “No, nothing, nada.”

Macroinvertebrates and aquatic macroinvertebrates were terms introduced to the RRBSA volunteers at the NOAE orientation session, terms that reverberated throughout the citizen science program. In addition, the term was but one of many scientific vocabulary examples in which participants thought they knew the definition of the term prior to the RRBSA only to realize they could not articulate it or were all-together incorrect in their prior belief. Whereas the participants were never pointedly asked to define scientific vocabulary, their responses to unstructured interview questions repeatedly demonstrated that they had learn the scientific vocabulary and are able of using them terms in the proper context. When asked about his role in the data collection process, Juan explained, “I helped collect the actual animals and collect them.” When I asked, “Animals?” Juan replied, “Well, aquatic macroinvertebrates, but they’re still animals to me,” demonstrating his knowledge of the term, and through his sarcasm, a basic element of the definition. Among the more entertaining of these cases was Kristen, who when asked early on what she had hoped to gain from her participation in the RRBSA responded, “…I wanted to learn about bugs, (brief pause) well insects, (brief pause) macroinvertebrates now. Now I know what they are, but initial thought was bugs,
“Sorry.” Kristen also presented a brief discussion on how having learned the proper scientific vocabulary regarding biomonitoring and macroinvertebrates, she found herself struggling to communicate properly after years of prior vocabulary understandings that were incorrect. Kristen shared her difficulty in discourse in the following:

With terms and vocabulary, I always wanted to explain and teach everything to my parents and boyfriend about everything biomonitoring. Nobody knew anything and if you wanted to talk to them about it, you had to teach them or explain what was going on. The whole thing was made so much harder because now I had to carefully think about what I was saying and trying to reverse all the previous beliefs I had that were wrong, stated Kristen.

In addition to revealing a self-assessment of elevated science vocabulary knowledge, Kristen demonstrated these elevations in her response; properly relaying the citizen science program as “biomonitoring,” and revealing her assertion of an elevated civic science literacy with her family and boyfriend.

Of the 41 terms presented during NOAE sessions, including macroinvertebrate and aquatic macroinvertebrate, many of the scientific vocabulary was brand new to the participants. Because participants were not asked or led into using proper scientific vocabulary during the course of their interviews, the proper use of the scientific vocabulary in discussing the RRBSA during their interviews is evidence of elevated civic science literacy. For example, when asked if he could replicate his RRBSA actions at another stream on the other side of the country, Eric responded, “Obviously, everything from using the seine, water temperature, substrate analysis, the smell and odor of the water, all the physical attributes of the water, and then, among other things, identifying all the aquatic macroinvertebrates collected in the reach, (slight pause) yeah! I would just need the proper dichotomous key for the aquatic macroinvertebrates found in that region.” Eric demonstrated an elevation in his civic science literacy through the proper
use of scientific vocabulary with the terms “seine,” “substrate,” “aquatic macroinvertebrates,” “dichotomous key,” and “reach” in his response. His proper contextual use of RRBSA scientific vocabulary was not a static event and continued throughout his interview responses. When asked if his participation became routine, even boring, and he knew what he would collect before he sampled from the reach, Eric told me, “certain things such as caddis fly larvae and midge larvae (pause), we highly suspected we would have high numbers of those orders,” identifying the proper taxonomic classification through the term “order,” and the correct aquatic life stage of the macroinvertebrates, “larvae.” The proper scientific distinction in the holometabolus and hemimetabolus life stages of macroinvertebrates collected and identified throughout the research was not unique to Eric and something that was discussed as part of the NOAE sessions. Mary mentioned her excitement in finding a “damselfly nymph,” and Juan expressed his surprise at “the quantity of stuff like larvae, naiads, caddisflies, water pennies, and so on.”

In addition to the life stages of macroinvertebrates, the participants also demonstrated their vocabulary knowledge of entomological taxonomy in their interview responses. Eric’s, and other volunteer’s, proper use of the scientific term “order,” along with Gerald’s previous response regarding “species,” are but two of many examples where participants verbalized a taxonomy vocabulary understanding in their interview responses. Marie demonstrated a great example of using Linnaean taxonomic classification sequences properly as she discussed her surprise about temporal stream dynamics – an important part of science process understanding that will be discussed later. Marie additionally shared how surprising it was to her that “the stream reaches are
so different just a half-mile apart or so,” properly using the vocabulary “stream” and “reach,” and continuing, “I had no idea how many different species of one particular insect order there could be.”

Not all the scientific vocabulary presented to the volunteers was directly related to macroinvertebrates. It was also critical that volunteers understood the scientific vocabulary related to both the fluvial systems that hosted aquatic macroinvertebrates during certain life stages and the interactions between systems affecting stream health. One of Walter’s open-ended responses characterized an important piece of this scientific vocabulary and his new knowledge gained from a NOAE session, “pollution covers a lot of ground that includes our interaction with the stream;” understanding that pollution as a scientific term includes more than chemicals and that any channelized water flowing down slope is scientifically a “stream.” In discussing his many roles in the RRBSA, Rick mentioned that in addition to “using the seine,” he performed “visual observation of the riffle, substrate, and the whole reach,” a common statement incorporating the proper use of the scientific vocabulary. A second example that stood out was when Juan was asked if anything surprised him during the course of his participation? A perturbed Juan remarked, “Anytime I thought of turbidity, I thought of turbidity currents which was so far off I had to retrain my mind. Even things like substrate, I thought I knew what they meant - and I wasn’t always far off - but you learn more specifically what they are.”

Whereas Juan was the only participant to directly address a scientific homograph and the diverging locution of scientific vocabulary across scientific domains, many participants commented on having to retrain themselves to understand the scientific metric that
defined boulder, cobble, silt, and other clastic particles functioning as a substrate habitat factor for aquatic macroinvertebrates.

A final example, while perhaps not directly viewed as a piece of scientific vocabulary, important for the researcher and the sponsoring organization to communicate was the meaning of “citizen science” and how the volunteers serve an invaluable role for both their community and the scientific community. Many of the volunteers seemed uncertain as to the value of this brief discussion, it did not concern aquatic insects, macroinvertebrates, or any of the necessary scientific vocabulary or process understanding knowledge needed to participate in the research. However, both as a scientist and education researcher, I was pleasantly surprised when the scientific vocabulary and context consistently emerged during the interviews four months later. Perhaps the most important response can from Rick who was asked about the impact he hoped his data would have on his person, family, and/or community. Rick responded, “I would hope that the results will in some way show that citizen science is a valuable part of not only research, but education for my family and community.”

**4.2.3 Civic Science Literacy & Science Process Understanding: Quantitative Results**

Part two and three of the self-report survey specifically addressed the participant’s scientific process understanding, and the narratives contained later within this section continue to demonstrate the participant’s elevated civic science literacy through science process understanding. The understanding of scientific processes can only emerge as a result of successful experiential learning in which the volunteer begins their learning journey by taking the necessary scientific vocabulary and field methods – as learned at NOAE sessions and through mentorship - with them into the environment and become
fully immersed in the research; reflection, generalization, and the understanding of overarching principles must follow in kind. “Experiential learning,” state Walter and Marks (1981) in support of Coleman, “is operative when participants are fully involved, when the lessons are clearly relevant to the participants, when individuals develop a sense of responsibility for their own learning, and when the learning environment is flexible, responsive to the participant’s immediate needs (p. 2).” Each item on the self-report survey was designed to be clear and specific enough so that each participant, regardless of his or her individual experiences, could relate to the line-item measure by virtue of having executed the totality of the research and enveloped experiential learning framework.

Part two and three of the self-report survey specifically addressed the participant’s science process understanding for 87 individual processes/dynamics/procedural skills related to the RRBSA. As with the analysis of scientific vocabulary, careful consideration was made as to the best measure to capture data regarding the more intrinsic elevations in science process understanding. A mixed-methods approach was designed to incorporate self-report surveys and both structured and unstructured interview questions. Many of the line items appearing on the scientific survey were confirmed for the survey based on the learning objectives guised in the RRBSA.

Towards maximizing the validity of the research results related to scientific process understanding, particularly in giving participants ample time to reflect on their learning, research participants were mailed a survey instrument and also engaged in interviews. The survey instrument (Appendix C) employed a “Before Research” and “After Research” four-point Likert scale designed to enable the participants to self-report their
scientific process understanding, both prior to the 2010 RRBSA and following the 2010 RRBSA, along a defined continuum that helps to prevent participants from making judgment calls on their self-defined conceptions of science process understanding. As with the measure for scientific vocabulary knowledge, the Likert scale was designed to lend clarity to the self-reporting measure and not for the application of statistical analyzes that weigh the numeric values of each score along a measurement scale. Returned surveys were re-scored using a dichotomous scheme in which all responses of “0,” “1,” and “2” were recoded to “0,” and all responses of “3” were recoded to “1.” This dichotomous construct was conceived to capture only a true scientific process understanding by only counting “3,” “I can verbalize the scientific process/dynamic/discovery/[procedure] in a scientific manner to another person,” as an indication of civic science literacy. Likewise, all other responses on the survey, including everything from “0,” “I am unfamiliar with this process/dynamic/discovery/[procedure],” to “2,” “I can verbalize the process/dynamics/discovery/[procedure] to another person, but not in a scientific manner,” is coded to indicate that civic science literacy was not achieved; even if marked improvements had been self-reported as a result of the volunteer’s participation in the 2010 RRBSA citizen science program. The summation of the dichotomous data for each participant, both indicating acquiring civic science literacy and failure to acquire civic science literacy, was entered into an Excel spreadsheet. The spreadsheet was then imported into SPSS 19.0 for Windows for analysis.

Data regarding scientific process understanding was collected from 15 participants for 87 different scientific processes introduced piece-wise through scientific vocabulary and enhanced experiential learning designs during NOAE sessions throughout the RRBSA.
In testing the statistical gains in scientific process understanding as a result of the participation in the RRBSA and experiential learning while conducting citizen science research, a paired t test was performed. Paired t tests have greater power than unpaired t-tests particularly given that the confounding factor of “noise effects” is assumed to be similar in the before research ($\mu_1$) distribution as the after research ($\mu_2$) distribution since the participant pool is unchanged (David & Gunnink, 1997). The null hypothesis is expressed as:

$$H_0: \mu_1 = \mu_2$$

or, equivalently:

$$H_0: \mu_1 - \mu_2 = 0$$

Statistical analysis was performed using SPSS 19.0 for Windows. The obtained t-test score of the difference between before research scientific process understanding, n(8.60, 11.87), and after research scientific process understanding, n(42.47, 23.88), is 6.57 (Table 2). At a significance level of 0.05 ($\alpha=0.05$), the t critical value for a two-tail test is 2.145. Therefore, the null hypothesis ($t_{(14)}0.05 = 2.145, p<0.001$) has been rejected and it has been concluded that there is a statistically significant difference, at the 0.05 level, between the participant’s scientific process understanding before the research and the participant’s scientific process understanding after research. This result indicates that the participant’s scientific process understanding, by conventional criteria, is extremely statistically significant; indicating the marked improvement made during the course of experiential learning during the RRBSA. This result, given the unlikely familiarity of the processes, dynamics, and procedural skills outside of the RRBSA, speaks volumes for the effectiveness of elevating civic science literacy through the construct of, and
Table II. Science Process Understanding Statistical Results. SPSS 19.0 paired t test results for civic science literacy gains in science process understanding.
andragogical enhancement of, experiential learning catalyzed by a NOAE component within citizen science programming.

**4.2.4 Civic Science Literacy & Science Process Understanding: Qualitative Results**

When applied to NOAE, civic science literacy, and the prevailing context of this research, experiential learning is the voluntary immersion of an adult learner in an out-of-doors learning environment to execute or observe an action, critically reflect on the effect(s) of that action, build generalizability, and develop a concrete understanding of the overarching scientific vocabulary and principles towards improving one’s civic science literacy. The result of successful engagement in experiential learning can be demonstrated in a variety ways, and, as discussed by Barrett (2007), need not be restricted to quantitative modes of evaluation or employing numeric symbology to demonstrate scientific understanding. “Restricting enquiry to those things that can be exactly measured would mean denying many of the benefits of alternative modes of inquiry,” states Barrett (p. 115).

The second phase of data collection was participant interviews, comprised of both structured interview questions and unstructured interview questions. The structured interview questions are purposefully designed to be succinct, short-answer questions towards gaining knowledge on the participant’s background, their motivation for participation, their experience throughout the course of the program, their personal feelings regarding the NOAE, and to briefly assess their level of civic science literacy both prior to participation and following participation. The unstructured interview questions, roughly sketched as a series of incomplete questions designed to procure specific data, executed themselves more as a secondary, open-ended structured format
centered upon key elements and responses provided during the structured interview process.

Following the interviews, all participants were provided with an immediate opportunity to read, and edit if necessary, their responses (members check). Upon completion of the tenth interview, a time when no further interviews could be or were scheduled to occur, an analysis of common themes was performed. This methodological decision allowed general findings to begin to amalgamate into broad themes (situation codes) that permeated the research into more specific themes (process codes) and the events attached to them (event codes) (Appendix A). The situation code of interest at this point of the results is an elevation of civic science literacy with a focus on those themes related to science process understanding.

Conveying the data pertinent to demonstrating science process understanding is a difficult task given the dozens of pages of interview transcripts and hundreds of responses related to each facet of experiential learning and an elevation in the participant’s science process understanding. After careful consideration, the totality of the individual experiences and science process understanding is believed to be best conveyed through the narratives of the participants themselves. To accommodate this, the research results for this section will more intimately introduce you to five of the RRBSA participants: Kristen, Rick, Gerald, Marie, and Walter.

Kristen is a 25-year-old female with a B.A. in Communications and Public Relations. The bubbly blonde loved being out in the field and was the first to volunteer to help wherever it was needed. Kristen had a passion for the outdoors and was no stranger to volunteering, having provided her time at a local nature center and a community group
dedicated to environmental health. When asked to rate her knowledge of science and technology on a scale from one to ten, with one being none and ten being an expert, Kristen rolled her eyes and stated, “Oh God! Definitely a one! Can I be a fraction?” I was surprised by her response given her previous community activities and volunteerism. I asked her if there was a scientific discipline she felt particularly strong in and Kristen responded, “Maybe dietary stuff. I am a vegan and exercise is also an area I am pretty familiar with on a passing basis.”

Kristen understood the importance of being immersed in the environment of study even though, as Kristen shared, “it was my first time ever doing something like that…you have to be in the field if you want to learn the topic.” As with all the volunteers in the beginning of the summer, Kristen’s actions on the environment were isolated to the protocols outlined by the ODNR SQMA data sheet. “Cleaning the rocks, using the seine, identifying the insects, taking water temperatures, getting GPS coordinates,” Kristen elaborated, were among the many actions she executed in the field. When asked if she had ever done any of those actions in the field before, Kristen humored me by stating, “I have walked in a river before and kicked a few rocks but that is where the previous experience ends.”

Kristen’s science process understanding increased as the RRBSA progressed throughout the summer and into the fall months. She continued with her field experiences and talked about how, “We took our time and observed our surroundings. It served as a social time – I mean you do not see the other volunteers except when you’re in the field – but your also bouncing your memories of the site off each other, how it changed, what was different, all that stuff,” Kristen concluded. These advancements
became evident when I asked Kristen about her thoughts away from the field. “I told my family, and boyfriend, and friends about what I was doing. I also talked to other people… at the cookouts and sometimes just hanging out at the site afterward,” Kristen stated. “It wasn’t until the program was over and I had time to reflect on the whole experience, including teaching what I was doing to my family and thinking about what we had found and why it was there (pause)...I guess I just didn’t realize how much I had learned and how detailed and complex that knowledge was...Had I known that before hand, I probably wouldn’t have volunteered,” Kristen concluded.

The idea that Kristen’s science process understanding evolved to the point of meeting civic science literacy was solidified when I asked Kristen if her role in the field ever became routine; “another day, same old thing?” Kristen enthusiastically stated, “No! That is one thing that was great about biomonitoring and being out in the stream. You realize just how dynamic and how quickly things in nature change….The system differences [between reaches] certainly make you more aware of those differences that may exist, especially as the seasons started to change.” Kristen finished, “It definitely made you more aware of your surroundings and how it [the stream] could affect the type and number of aquatic macroinvertebrates….insects can show the quality of water and the human impact and how the whole system, starting at the bottom of the food chain with the aquatic macroinvertebrates, is impacted by humans.”

Rick is a 37-year-old male who has forged a successful career as a restaurant manager and waiter at various fine-dining establishments. Like Kristen, the RRBSA was Rick’s first experience in the field. “It was very cool sounding” Rick responded to my question of why he got involved. “I knew the research was going to be cool,” Rick
continued, “and it sounded like a neat way to go down to the park and explore an area of
science that I had never explored before.” The tall, heavyset gentleman was an imposing
figure but had a sense of humor that always kept you laughing. While I do not think he
was trying to be funny, Rick caught me off guard when I asked him to rate his knowledge
of science and technology on a scale from one to ten, with one being none and ten being
an expert. Rick stated, “I would say I am a six. I am above average.” Without
questioning his reasoning for a number I thought was grossly inflated, I continued
through the questions and ultimately got to the series of unstructured questions
addressing science process understanding.

Like his colleagues, Rick never questioned the importance of immersion. “I am going
to learn more by going out and getting my hands dirty and being in the environment of
study opposed to looking at a book, listening to a lecture, or watching a television
program,” Rick explained. When asked about his roles in acting on the environment,
“Everything that was asked,” was Rick’s succinct answer. However, Rick went on to
give a more thoughtful answer that took the interview in a more serious
direction. “I
definitely got better as I went along throughout the research….Each time we went to the
river, I got better at what we were doing and understood better what it all meant,” Rick
continued. The jovial Rick shared with me the importance of discussing his immersion
and actions with his wife and his niece, who was always excited to hear about what
aquatic macroinvertebrates Uncle Rick had found in the stream that day. “Anytime I ran
into someone that asks ‘How’s your day?’ or ‘What have you been up to today,?’ I talked
about it,” Rick shared. These discussions, whether explicitly known to Rick or not, were
verbal reflections of his immersion and action during the research; reflections that led to a strong science process understanding.

In elaborating on the science process understanding gained through his experience, Rick told me, “Every time we went out in the field it was different…it seemed like something crept up and surprised you every time you were there. There were more components to the data collection than I had originally considered.” When asked to elaborate on this comment, Rick replied, “I wouldn’t have thought that substrate analysis was such an important part of this type of research but in retrospect, it makes a lot of sense.” Even when the consistent identification and counts of aquatic macroinvertebrate orders like the caddisflies became slightly mundane, Rick was adamant in reminding me that there was nothing left to chance and or worth guessing. “That’s why you do the research,” Rick told me later in the interview.

In a humorous, yet serious manner – a trick that only Rick could manage – I asked him near the end of the interview if his findings contradicted any previous beliefs he had held about fluvial ecosystems. “I think the presence of certain orders didn’t necessarily mean what my preconceived notions were about the quality of water. I mean, anytime you think leeches, you think of Rambo being pulled from the cesspool and that guy plucking them off with the knife. But water pennies and leeches hanging out together [something he had observed] really makes you think about…what your preconceived notions are and what they will be in the future. I think I am done with preconceived notions.”

Gerald is a 47-year-old male who approached every aspect of the RRBSA methodically and scientifically, an attitude supported by his B.S. in Biology, fieldwork in
Burundi with gorillas just two weeks after Diane Fossey’s murder, career as a compliance officer for a public works government agency, and the fact that he took his nieces and nephews (aged three, six, and eight) out in the field for every collection cycle. While Gerald was the most experienced field worker among the volunteers, “Even an old dog learns new tricks,” Gerald shared with me. The gray-haired, leather skinned Gerald, like all the participants in the structured portion of the interview, was asked to rate his knowledge of science and technology on a scale from one to ten, with one being none and ten being an expert. “Shit. Probably like a three,” Gerald told me. But then Gerald went a step farther than his interview predecessors by qualifying his answer. “To be a ten, you would have to be a master of everything. I don’t think it’s possible,” Gerald stated.

Immersion and action in the environment was about as ingrained as can be possible with Gerald. I did not think I would even get a response from Gerald that addressed these facets of experiential learning during the unstructured interview portion, but Gerald verbalized his understanding of immersion and action in stating that, “You can only learn so much from a picture, you have to be out there in real life in order to know anything and that was what this was. Without immersion, I never would have learned a fraction of this information.” Before I learned that Gerald felt that he had not done any true fieldwork in nearly 25 years, I asked him about his reach visits and tried to elucidate his reflections on his actions (something I thought would be difficult for him to articulate). “We did a lot of comparisons from prior visits,” Gerald started. “For example, there are more leaves in the stream now and they are collecting on the boulders, or this tree is down, or the stream is shadier today even though it is the same time of day as before,”
Gerald continued. More than ten minutes had likely passed before Gerald completed his response about the one reach his team visited, reflecting on every detail from urban infrastructure to migrating riffles. But considering that biomonitoring and aquatic macroinvertebrates was a new area of exploration for Gerald, how did he process all that data and develop science process understanding? Gerald answered this question for me, inadvertently, near the end of our interview. “You know, one more thing,” Gerald said, “at the very beginning you are simply trying to make sure you are identifying everything correctly and that the data is as correct as possible. But as the summer goes on and your knowledge improves, you have more room to start to look at things differently and…the details become more advanced.”

Gerald and his team, like all the volunteers, was a tremendous asset to the RRBSA. Gerald was a unique example in that one might think that his previous biology degree and professional experience implied that his scientific vocabulary and process understanding was already established. But the domain of study was completely new to Gerald and the dynamics and processes acting in a natural fluvial system were well beyond anything he had ever experienced. Gerald shared with me later that not only did he learn a lot of new scientific terms, but also learned a whole new aspect of process understanding that he felt would be an advantage to him for the rest of his life. Gerald finished by sharing with me that the RRBSA, “opened my eyes to a number of things starting with effective ways of gauging water quality without doing invasive chemical testing. You do not need expensive equipment to run a test, you need to train people to have an interest in collecting data that can change people’s lives.”

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Walter, a 21-year-old male, and Marie, a 22-year-old female, are introduced in unison due to their similar backgrounds. Marie and Walter are seniors in college, both pursuing degrees in the natural sciences. Both shared an impetus for volunteering for the RRBSA citizen science program as a way to gain experience in fieldwork and research methods; skills that would enhance their graduate school applications. Similar to all the participants, Walter and Marie were both asked to rate their knowledge of science and technology on a scale from one to ten, with one being none and ten being an expert. Walter stated, “I know there is so much science that I do not know anything about. I would say about a five, but maybe I am giving myself too much credit.” Marie would likely agree with Walter’s idea of “too much credit,” as she responded in a similar breath, “I mean, there is a lot out there that I do not know, I mean a lot! I would say probably like a two or three.” These responses, including their explanations in this portion of the structured interview demonstrates an important point lending credence to the choice of a qualitative methodology in supporting evidence for an increase in science process understanding. It is perhaps impossible, and certainly random, to ask people to assign themselves an undefined value as a measure of some parameter. What is invaluable is their explanations; explanations that can only be captured through discourse.

Walter and Marie both understood the importance of being immersed in the environment. Marie made one of the most emphatic statements regarding the value of immersion and action in stating,

You can talk about insects all day, but to understand them you have to be completely immersed. Learning science is like learning a foreign language. If you’re really serious, you need to immerse yourself in that culture and surround yourself with the language to really learn it. The same goes for science.
Whereas both Walter and Marie expressed the importance of immersion and action on the environment in acquiring civic science literacy, both also carried a classroom mentality into the field at the start of the 2010 RRBSA; acting methodically, precisely, and stoical to some degree. Their experience from afar seemed more like taking a test than being relaxed to any degree conducive to process understanding. Fortunately, that would change when, according to Walter, “A bunch of us started to get to know each other and we even went to the bar together one night. We always talked about what we were finding.” Whether or not Marie was one of the volunteers Walter met up with at the bar one night is unknown to me, but, what is known, is that Marie also became more relaxed and reflective of her field experiences as they progressed. Marie may have found the reason for this change herself when she told me, “I used the dichotomous key but having someone in the field to mentor you and that can clarify and point out characteristics of insects the first time you find them is important. From then on, you start to learn by repetition and by looking at the environment and the way things are all interacting and changing.”

As was the case with all the participants, Walter and Marie’s science process understanding increased as the RRBSA progressed throughout the summer. These advancements began to emerge as the interview methods changed from structured to unstructured questions. When asked about his general experiences throughout the program, Walter stated, “There were some things in the protocols that became routine and that allowed us to focus on finer details in the field.” Similarly, Marie began to changes within the system, “maybe, like, the second time we went out…and you even get excited to try and find that one big change, whether it’s the insects, a type of rock, or
something in the environment.” Both Marie and Walter became much more astute to
their immersion and actions and garnered time to reflect on their experience only after
becoming more versed in the protocols and the identification of aquatic
marcoinvertebrates; a moment that allowed them to relax in the field.

Walter reflected on meeting his personal goal of volunteering in stating, “Now I have
a general understanding [of fieldwork] that doesn’t include books, equations, or
calculators. There is something bigger than books…experience.” His response
continued in length, and fortunately, became more humorous while making an important
point. “I realized you do not have to be a PhD professor in riffle beetle larvae to detect
them in a stream system and know what their presence means,” Walter emphatically
stated. I do not know any PhD riffle beetlologists personally, but his point is loud and
clear. A part of science process understanding also includes an understanding of your
own capabilities and biases - something both Walter and Marie challenged early in the
program. Fortunately, both Walter and Marie, like each of the participants involved in
the interview process, verbalized their emergence from the RRBSA as better scientists;
armed with experiential learning and the fundamental knowledge that they are not only
capable of performing scientific research across domains, but also confident in their
ability to maximize their experience through a newly developed science process
understanding.

Kristen, Rick, Gerald, Walter, and Marie, as with the other interview participants,
clearly demonstrated marked increases in their science process understanding and, as has
been previously discussed, incorporated the proper scientific vocabulary during the
interview process. While they collectively serve as an excellent collection of narratives
representing the interview participants, each of the volunteers interviewed shared similar experiences and gains in their science process understanding. For example, Eric shared the following:

Every time I went out in the field, I was always looking to see how things changed or what was different and how the reach and its dynamics were fluctuating….I had hypothesized about what we would find depending on water depth and current, but it was always different each time you went out in the field…. [It] made me more aware of how the site might change based on what was going on upstream… each progressive outing provided for more base information about what you were observing. Your observational skills, my ability to understand what I was looking at, became better each time.

All of the participants voiced their confidence in being able to replicate their immersion and action at any stream, any time. Their confidence in developing hypotheses, testing those hypotheses, and developing generalizations bases on repeated measures was not only elevated, it was considered “a must,” as shared by Terry, “to truly understand science.”

4.2.5 Assertion of Civic Science Literacy

In creating a democratic citizenry in the sciences, states Jenkins (1999), “the rhetoric is that citizens need to be scientifically literate in order to be able to contribute to decision-making about issues that have a scientific dimension, whether these issues be personal… or more broadly political” (p. 703). As such, civic science literacy is not only to be valued as a tool towards democratic change; it is just as importantly a tool for personal development and social transformation. With an elevated level of civic science literacy, gauging the assertion of that knowledge, as “a tool for personal development and social transformation,” by the participants in social forums within a scientifically evolving society seems little less than a daunting task, as best. How does one create measures capable of capturing the themes and events of an action that may not occur for
weeks, months, or even years? The structured interview was, in part, designed to do just that; lead the participant into detailing any accounts, or perceived future accounts, of personal development and/or social transformation. However, after the first interview, it became abundantly clear that by asking the participant in a pointed manner, they fumbled to think of accurate accounts of personal development and social transformation. However, with the same participant, those accounts arose on their own – in context - during the unstructured portion of the interview. Believing that if you just let the participant talk, although a risky endeavor particularly if the necessary data fails to arise, it would prove to be a successful risk leading to more pure and holistic accounts of personal and more broadly social assertions.

As has been discussed, American adults are far too reliant on a variety of mass media outlets for their acquisition of scientific knowledge - knowledge that is often succinct, serving other interests, lacking validity, and/or, far too often, blatantly false; a sentiment shared by Gerald who shared, “It is just a case of politics and who has the most ability to sway public opinion.” Part of being civic science literate is taking control of your own science knowledge through improving one’s scientific vocabulary and science process understanding; both to act within the sciences for one’s self and to navigate the inundation of science-centric issues faced on a daily basis. “I love learning science firsthand,” stated Eric. “Since 1994, I have grown up in the age of global warming and have therefore grown up in the age of scientific conflict and controversy,” Eric continued. As Eric alludes to, it is an important aspect of civic science literacy to use that knowledge to improve one’s personal development in the sciences by asserting that knowledge through self-confidence, conversation, action, and by telling this researcher the way it is.
One ubiquitous, simple example that stood out was Kristen, who when asked if she was aware of any impact the data results would have responded, “Impact? Really? Well it had an impact on me!”

Many participants used their elevated civic science literacy to reverse long held beliefs about the water quality of the Research River. Walter summarized the sentiment of many citizens in stating, “Well, anybody that doesn’t do these things thinks everybody of water in [the area] is going to catch on fire; they all assume they are shit,” a belief apparently held by many of the participants prior to their participation in the RRBSA.

Eric shared with me, “I always thought the Research River was basically a cesspool and wouldn’t sustain much life at all (slight pause), that was my initial notion. I didn’t realize how much lives in the water and how good the water quality actually is.” Similarly, Juan, a recent transplant to Ohio from Philadelphia, told me, “I didn’t realize the [Research River] was as clean as it was,” an interview response iterated by Kristen, Rick, Mary, and Marie, as well. But the participants also discussed how they became advocates for the Research River’s health, opposing those individual and social networks that held oppositional beliefs to the scientific data collected throughout the RRBSA.

“You can’t always rely on what you hear,” Walter told me, “The data and the research tells the real story and most people, hell, hardly anyone, ever get a chance to get so involved to know the whole story like we did.” This made the assertion of that scientific knowledge on the part of the participants that much more important. Gerald, enthusiastically brought home this point, “I talked to my family, friends, and coworkers about what we were finding and how much we were finding and how the water quality is
pretty darn good. Some people tried to debate me and it was like, no, I’m not here to debate, I am telling you!”

Gerald was not a unique example of the assertion of civic science literacy gained through the RRBSA. All of the participants interviewed shared stories of asserting their civic science literacy towards educating others on the science of the Research River and the finer scientific details related to the RRBSA. Terry told me, “I talked to my parents, coworkers, and friends about what I was doing and I told them about what we were finding every time I went out. They were always interested, but I think they were just mostly amazed at the way I was talking…oh yeah, the student has become the teacher.” In addition to Terry, Kristen, Mary, and Marie shared similar stories of talking to family, boyfriends, and coworkers, asserting their civic science literacy even when the parties were, perhaps, obligated to listen.

Although no more important a form of assertion, the pressure to speak clearly and scientifically becomes challenged when those assertions are solicited! Eric found himself constantly challenged by his father-in-law. “Every week that I did that [biomonitoring], my father-in-law was interested in how things were changing,” Eric told me. “But that was just the beginning,” he continued, “next thing I know, I have the curse of being the science guy in the family and trust me, you don’t want to be wrong.” Rick also found himself in a position where his assertion demanded precision. Upon learning that Rick was involved in the RRBSA, a coworker began asking him for the details of the citizen science program and the data he was finding. “She was home-schooling her daughter and had interest in teaching my findings,” Rick stated. Marie shared a similar story of a coworker interested in her research “because,” stated Marie, “he was big into fishing and
interested in the mayfly nymph life stages and what we were finding.” Each of these assertions, like all of the assertions discussed in this paper, requires an elevated degree of civic science literacy, and, sometimes, a high degree of patience. “You tell people you are doing a bioassessment and the term itself can sound complicated to them,” stated Walter. Fortunately, Eric shared, the solution is simple: “You do the research, you do the work, and you know the data is correct.”

The participant’s assertions expanded well beyond their person and immediate family, friends, and colleagues. Assertion can manifest itself as a potential to act and react for social transformation, a static state just waiting to be challenged. According to Jim, who holds a B.S. in Environmental Science, when asked if his participation in the RRBSA changed the way he thought about natural systems and the larger systemic nature of science, Jim responded,

I think it has shown me that regardless of your scientific education in a field that you know very little about, I mean, I was on the same footing as someone with no scientific education at all. All that education didn’t translate to jack out in the field….I also think these types of programs should be performed more often to get more individuals involved so that the data can grow and more people can become aware of how their natural systems operate and their health.

Jim was not alone in his assertion that both the larger community was fully capable of executing the science of a renewed citizen science program – a fact that challenged the way he thought about his own knowledge and education – and that they should be executing the science of a renewed citizen science programming. “When there is a community issue, you have to bone up and prepare to make educated decisions,” Eric told me. A combat veteran of the Gulf War, Eric continued by stating, “I think it is the duty of every American, no matter what your politics are, to help in the military, and the duty of every person to engage in stuff like this [citizen science programming] for both the
organizations that rely on the information and to better increase scientific understanding for yourself.” Many of the participants shared this assertion and, in some cases, pledged to make it a personal goal to involve more American adults in citizen science programs with the explicit goal of increasing civic science literacy and taking control of science in society. “It was amazing to me how much a handful of people can do to help themselves and society,” Eric concluded.

For some of the participants, their assertions for action were directly related to the data collected during the RRBSA and the goal to maintain the integrity of their work. When asked if he knew the purpose of the RRBSA, Walter responded, “I knew it was geared towards collecting data for an assessment as to the health of the stream. The more I was involved, it became even more apparent why it was important and how the data was important.” While many of the participants shared similar sentiments, Juan took his assertions one step further in stating, “Even though I know I wasn’t the one crunching numbers or writing policy, I was out there every few weeks collecting data. Without data, you got nothing to talk about,” clearly asserting an authority and ownership for the data and its usage by the sponsoring agency. Terry asserted his ownership of the data and the development of civic science literacy, but trusted the sponsoring agency to make the proper decisions regarding the data’s use. “Our research is going to help the reservation,” Terry stated, “and if that helps their continued existence, or the acquisition of funding, or maybe a property easement, than that is something they will do and I know our research has helped.” In a final breath, other participants were more directly assertive in their faith of the sponsoring agency to address issues congruent with their own politics, a muddled aspect of civic science literacy in which the policy process is pseudo-
synonymously a scientific process. “The reservation is going to take this data and use it and learn better how to work on problem areas,” Jim was confident. “And,” Jim continued, “all this gives me piece of mind that the park is able to get data like this so that they can institute their programs to continue conserving the park.”

A final aspect of civic science literacy assertion melds personal development and social transformation, a shift towards becoming more directly involved in democratic process. “I could not believe that that tributary was channeled into the Research River, it was disgusting and definitely affected the habitat quality of the stream,” Mary told me about her reach. “I am going to write a letter,” indicating that she intended to assert her civic science literacy towards bottom-up policy for the benefit of the stream and a natural system enjoyed by millions annually. Gerald shared a similar assertion for creating democratic change in discussing a local stream system near his own home that was becoming increasingly discolored and was not hosting any EPT taxon aquatic macroinvertebrates. “We have conveyed to folks the information that we have acquired and the information gained through the programs and cookouts,” Gerald told me about his first step towards change. Gerald later told me that if the concern was not taken seriously, “I can guarantee you that I will be at city hall before they even open the doors!”
As our globally expanding society becomes increasingly embedded in science and technology that both affects individuals and contributes to the overall public welfare of American society, there has arisen an important need to improve the civic science literacy of our democratically enabled adult populace towards both the betterment of their personal, familial, and communal lives and improving their capacity to understand and facilitate the inundation of information in our science-centric society. To effectively act both for one’s person and as a member of society-at-large through discourse, understanding, and objectivity, American citizens must have a general understanding of both the scientific vocabulary and scientific processes that affect these increasingly salient personal, public welfare, and policy-based science issues. But today’s American adult is grossly deficient in civic science literacy. A 2007 poll by Jon Miller of Michigan State University revealed (as cited in Brainard, 2008), “only 25% of American adults are considered scientifically literate” (p. A9). Miller suggests that the only way to improve civic science literacy is to begin by improving the public’s understanding of scientific vocabulary and then building their repertoire of skills in understanding scientific processes and the impact that science has on their lives (Miller, 1998; Miller 1993). The
qualitative and quantitative results of this research, both individually and as a collection, clearly demonstrates that dramatic improvements in the scientific vocabulary and science process understanding of American adults can be achieved through a renewed citizen science paradigm incorporating NOAE. Even with a relatively small – although statistically acceptable – sample size, the results for all phases of the research were highly significant; an amazing reversal of general beliefs given the temporally controlled nature of the RRBSA. In addition to elevating the civic science literacy of the volunteers, the RRBSA maintained the fundamental tenet of citizen science programming in collecting an expansive and statistically valid data set for the sponsoring agency to use in the addressment of scientific issues affecting the community-at-large.

While continuing professional education and lifelong learning has become the mainstay for science literacy development in professional realms, there are limited forums for American adults seeking civic science literacy in the natural and physical science domains for personal and social purpose. Those forums that do exist often undermine the maturity and rich history the adult learner brings to the classroom and treats the adult learner in the same manner as a child attending school. With documented barriers preventing formal education as a forum for elevating civic science literacy for most American adults, an unprecedented number of American adults are participating in nonformal and informal education programs centered amid natural science topics. Given its spatially and temporally expansive relevance, citizen science programming has become one of the more popular forums for science education but continues to circumvent science education and civic science literacy development in lieu of generating research data and publishable results. The focus of this research centered on the
predicament of how civic science literacy can be made a primary goal of citizen science programming without disrupting their value as data collection tools. Towards answering this question, this research merged with a long-standing, institutionally sponsored citizen science program, the RRBSA, and worked with the facilitating division to develop and incorporate NOAE as a hypothesized tool capable of generating marked advancements in the civic science literacy of volunteers; challenging the hundreds of citizen science programs that have preceded the RRBSA and the meta-analysis of experiential learning performed by Handler and Duncan (2006) concluding, “inquiry-based learning [experiential learning] focuses on scientific process at the expense of content learning” (p. 10). The renewed citizen science paradigm introduced and executed in this research successfully expanded the science knowledge foundation of volunteers through the traditional citizen science program redesigned to incorporate nonformal outdoor adult education and enhanced experiential learning towards marked elevations in the civic science literacy of volunteers. The mergence not only maintained the basic tenets of citizen science programming towards the acquisition of useful data in addressing scientific problems, it successfully elevated the civic science literacy of adult participants and elucidated how such elevations led to an assertion of that knowledge in social forums within a scientifically evolving democracy.

5.1 Reinventing Citizen Science to Meet Educational Needs

The success of the RRBSA participants in elevating their civic science literacy, and assertion of that knowledge, can be directly attributed to a renewed, more holistic, citizen science paradigm designed just as much for the volunteer as for the sponsoring agency. The fundamental problem facing American adults is a lack of requisite levels of civic
science literacy and the proper forum for elevating this deficiency. Traditional citizen science programming is in an ideal position to serve both the American populace and the scientific community towards efficacy in many domains by elevating volunteers to “field associates in scientific studies,” as was explained by Cohn (2008, p. 193). However, previous citizen science programs leave volunteers with little more than the pleasure of knowing that they have contributed to research that would otherwise be unfeasible; with little regard for the volunteer and educational advancements. But the average citizen chooses to volunteer for a multitude of reasons that extends beyond being philanthropic with one’s time, reasons that often begin with science education. Unfortunately, this most valuable of the volunteer’s goal in participation is rarely realized throughout the course of participation, only emerging as fragmented knowledge gained through self-guided, informal education. The renewed citizen science paradigm, more specifically the RRBSA, made major strides in reversing this educational deficiency and elevating the civic science literacy of volunteers through the creation of a more volunteer-centered, temporally and spatially controlled program with the addition of nonformal outdoor adult education (NOAE). NOAE sessions served several primary functions that enabled the RRBSA to transcend previous citizen science programming: 1) acknowledging the ability of volunteers in domains beyond those of hobbyists and mainstream, media-driven interests; 2) introducing the volunteers to the sponsoring organizations and working scientists; 3) educating the volunteer towards civic science literacy advancements through andragogical constructs; 4) facilitating experiential learning in accord with Coleman’s (1977) framework; and, 5) executing the program under the guise of the scientific
method, without intimidating the volunteer, towards procuring the highest degree of data validity.

5.1.1 Acknowledging Volunteer Interest and Abilities

According to Jeffrey Brainard (2008), “The reputation of science as boring and only for nerds is beginning to change” (p. A9). As was previously discussed, adults have an insatiable desire to learn on a consistent basis. Even within the most prevalent knowledge transmission mediums of today - television, magazines, newsprint, and the Internet – humans electively seek and are invigorated by the available knowledge and educational opportunities in the sciences that surround them. Many of the citizen science programs that preceded the RRBSA ignored this basic tenet and believed that citizen science programs could only be successful if the volunteer brought the requisite knowledge required for the research with them to the program. This belief is highlighted by the Cornell Lab of Ornithology (CLO) programs in which their recruiting for the Seed Preference Test program acknowledged, state Trumbull et al. (2000), “Ornithology is one of the few scientific disciplines to which amateurs can make significant contributions” (p. 266). Similarly, the CLO’s House Finch Disease Study centered their efforts on amateur ornithologists who brought some element of previous knowledge to the program (Cohn, 2008). In fact, the ubiquitous nature of citizen science programs centered on the study of ornithology (Birdhouse Network, Tucson Bird Count, Neighborhood Nestwatch, etc.) is not a coincidence. Many American scientific institutions firmly believe this is the only domain in which volunteers can assist in making a significant difference in citizen science programs; primarily due to both their previous knowledge in the domain and extensive numbers across the United States. According to The National Audubon
Society, current membership across the United States is “well over 500,000 and always growing” (personal communication, November 15, 2010).

But not all citizen science programs have been centered on ornithological research. The Road Watch in The Pass (RWP) citizen science program, a Canadian-based program, solicited and utilized volunteers from the general citizenry for an accounting of local wildlife – mainly mammals - that posed a threat to local drivers; a group that included the volunteers. The executing agency, the University of Calgary’s Miistakis Institute (MI), recognized that, “the local residents possessed a significant interest and level of knowledge concerning regional wildlife,” stated Lee, Quinn, and Duke (2000, p. 3). Whereas the MI acknowledged the interest of local citizens to participate in the RWP program, they also clearly voiced an belief congruent with the CLO in that the potential volunteers already “possessed a significant…level of knowledge concerning local wildlife.” In short, the MI made a minor stride in recognizing that members of the general citizenry are capable of assisting in scientific research that is not ornithologically centered, but stumbled in reverting to the prevailing ideology that volunteer participation requires the volunteer to bring the necessary scientific knowledge with them to the program.

The RRBSA, under the constructs of the renewed citizen science paradigm, ignored this basic prevailing belief of both what constitutes a good volunteer and who among the general citizenry can successfully execute the protocols of citizen science programming. In fairness to all the traditional citizen science programming that preceded the RRBSA, even the sponsoring agency of the RRBSA was hesitant with this maneuver; placing the onus on the shoulders of the facilitating agency and the researcher. But it was understood
that regardless of the volunteer’s level of science knowledge entering the program, “there is a great potential for increasing knowledge about science among participants,” state Evans et al. (2005, p. 591), throughout the program.

With aquatic macroinvertebrates and fluvial dynamics as the central focus of the research, it was not surprising that very few of the volunteers had any knowledge of the topic prior to volunteering for the program. Not only did the volunteers not have any previous knowledge in the topic of study, many participants of this research shared with me that they did not realize exactly what they were getting involved in. “The number of planaria and leeches just covering the net, pretty gross,” stated Mary. Similarly, Juan presented a general perspective of the research topic in stating, “Usually when you think of water you think of fish and turtles, but you don’t think of the quantity of stuff like larvae, naiads, caddisflies, water pennies, and so on; at least I didn’t realize!” Whereas one might think being immersed with leeches, aquatic worms, planaria, and even crayfish may have been off-putting and potentially led to attrition, the volunteers learned to embrace the organisms and, similar to the teenage participants of the Juvenile Scalloped Hammerhead Summer Shark Tagging Project, take ownership of their presence in a dynamic ecosystem.

If the volunteers of the RRBSA were not familiar with the research, the protocols, or the aquatic macroinvertebrates being studied, then why did they choose to volunteer? This is a question that I did not think I would be addressing during the course of this research, believing that the volunteers would, in fact, have some sort of interest in aquatic macroinvertebrates, fluvial dynamics, and/or stream biomonitoring. But as the data revealed, prior to committing to the RRBSA, a majority of the volunteers had no idea
what an aquatic macroinvertebrate was, what fluvial meant, or what biomonitoring consisted of. Due to this surprising *ad hoc* result that emerged from the research data, I do feel it is appropriate to take a moment and discuss the motivation of volunteers. If a renewed citizen science paradigm is to utilize volunteers from the general citizenry who have no previous knowledge or interactions in the science domain of study, we need to understand why those individuals choose to participate and excel, as Cohn put it (2008), as “field associates in scientific studies” (p. 193).

5.1.2 Understanding Motivation

Motivation is always a tricky topic to tackle due to the endless permutations and combinations one can find both among and between volunteers – each of whom is unique as a volunteer and as an individual. Towards the development of a typology that encompasses and embraces the motivations discussed by the research participants, the work of Henri Lefebvre and his ontological transformation of space was employed as a guiding paradigm towards a broad understanding of motivation and demonstrating that ALL [capitalized for emphasis] American adults are potential volunteers within citizen science programs employing the renewed citizen science paradigm. If the motivation itself transcends the topic of research and responsibilities associated with the execution of a renewed citizen science paradigm, the value of the data can be elevated while attrition is reduced.

The Research River and the wider significance of the natural system (space) was a resounding motivational theme. Lefebvre theorized, arguably hesitantly, that space is a social product; a construction defined by social entities. As a social production, space is a complex construction based on values and meanings affecting spatial practices and
perceptions. This concept is presented in his spatial theory and the ontological transformation of space employing the triad of spatial practice, representations of space and representational space (Gottdiener, 1993); with spatial practice being the dominant motivation.

Representation of space, states Lefebvre (1991, p. 33), “are tied to the relations of production and to the ‘order’ which those relations impose, and hence to knowledge, to signs, to codes, and to ‘frontal’ relations.” Simonsen (1992), in a review of Lefebvre’s theory, reiterates the connectedness of order and spatial codes to representations of space. The order serves as meaning, and the hierarchy of the significance of meaning, in affecting social practice. Furthermore, it brings to the forefront the idea of space as a bounded abstraction and reinforces the idea of uneven development and competition. From Lefebvre’s perspective, space is an abstract representation, abstract in thought, idea, image, and language.

Carved out over millions of years and reshaped during the Wisconsin Ice Age, stories of the reservation’s fertile riparian valley bounded by walls of rock reaching to the heavens served as a symbol of hope and prosperity for those who sought agrarian prosperity. Early maps showed the winding Research River and riparian plains depicted with honey jars, hay bundles, and other iconic symbols of agrarian wealth. It is the sensory-based accounts of the reservation that speak to the representation of space as a motivation for some participants. Many of the participants had visited the nature center and heard stories of the reservation long before immersing themselves in the space. Eric shared with me stories his grandfather would tell him, while Rick reflected on pictures of himself in the reservation as a toddler; times he did not remember but were captured in
the print. Gerald heard an awe-inspiring story as a young man that sent him “looking for those sandstone carvings” he had heard and dreamed about. In a similar breath, Juan shared, “when I was born, my grandfather bought me a subscription for National Geographic and it took years before I could appreciate it.” Colorful images of forests, volcanic eruptions, and rivers drove Juan’s passion to be in the out-of-doors and in the reservation as a child. Throughout the course of the RRBSA, Juan took hundreds of photographs of the natural beauty of the park, creating new representations of space for those who are lucky enough to view them in the future. The images, memories, and accounts, in their unadulterated form, serve as functions of representation. But the representations can only serve as second-hand accounts, and as such, cannot serve as representations of spatial practices.

Spatial practice involves the material environment; activity is produced and performed within the space. It embodies both the production of space and the consequential reproduction of space through time. In assessing Lefebvre’s ontological transformation of space, spatial practice is empirically observable (Grönlund, 2005). Capitalization of the human sensory organs allows space to be perceived; the way space is appropriated, dominated, and the manner in which the person is appropriated. Space, and spatial practice, is neither static nor crystalline. Space is dialectical as both the product and the producer. Dialectically, states Grönlund, “it produces it [space] slowly and surely as it masters and appropriates it.” Space as a product “is not to be seen as an object or a thing, but as a set of relations that intervenes in production itself,” Simonsen (1992) continues, “Spatial practice ensures continuity and some degree of cohesion” (p. 82). However, the
continuity and cohesion of social practice, Grönlund (2005) finalizes, “is the practice of a repressive and oppressive space.”

What would be of direct interest to Lefebvre is the question of who controls the mode of production and how labor is hierarchically reproduced. The reservation and its governing commission play a basic role in the relations of production. While the reservation is able to produce sustainability from its services, the reservation’s governing commission relies on a motivated pool of volunteers to produce and reproduce the space, particularly as it relates to conservation – a resounding theme among many of the volunteers. Marie shared her beliefs in stating, “Conservation is really important, particularly in an urban area that does not have a lot of green space.” For Marie, the conservation efforts that could be catalyzed by the RRBSA data was of prime importance in her decision to volunteer. Juan shared Marie’s sentiments and believed, “if the conservation efforts were not there, the [reservation] would not be there.” Gerald built on the conservation beliefs of many of the participants regarding how the space should be produced and reproduced in stating, “once you lost it [natural space], you lost it; the land, the water, the space.” The extreme side of conservation as motivation was shared by Kristen, who is involved with other conservation groups outside of the reservation, who vocalized, “I would leave the [reservation] as a protected, natural area where no one could go if that is what it takes.” Lefebvre believed (as cited in Unwin, 2000, p. 16) that “Nature is becoming lost to thought” and while natural space remains “the background of the picture,” it “will soon be lost to view.” In concurring with Unwin’s beliefs, it is difficult to contend that nature is nothing more than a space of the past. This belief, perhaps, presents a school of divergent thought between Lefebvre’s early twentieth
century European ideologies and the twenty-first century ideologies of an environmentally conscious American society.

The current spatial practice represents but one stage in the continued dynamic of spatial practice of production and reproduction. What is more profound is the impact of spatial practice on the previously conceived space (representations of space), and the yet to be discussed lived space (representational space) which Lefebvre refers to as symbolism linked to the “underground side of social life.” It is the social relation of individuals and the environment in which the relationship produces meaning for those who experience the space. The symbolism is connected to the rhythm of an individual life and spatiality, producing a meaning that enhances the individual’s ability to be human and exist as a member of humanity. The evolution of symbology and patterns of meaning are built within the history of the individual and are constantly produced and reproduced (Simonsen, 2001). Spatial practice is a meeting ground – a meeting of material and the existential – a meeting ground that motivated many of the participants. Eric discussed how “the valley is an awe inspiring feature…and you wouldn’t even know it was there unless you went into the reservation.” Rick told me, “I have vivid memories of the summers and watching the leaves change colors on the trees or the first snow fall collecting on the branches. I remember walking on these logs that were a little retaining wall by the nature center and I will never forget the first time I was able to walk on them without holding my father’s hand and how proud I felt.” For many participants, the reservation took on a very ecclesiastic symbolism. In talking about the importance of the park to her, Mary stated, “I was supposed to be in church (pause), and I never skip church! You’re gonna think I’m insane, but I spent an hour talking to a deer and the
serenity and peace that overcame me was incredible.” Needless to say, I did not think she was insane. I had already heard the existential relationship from other participants, like Terry who shared a childhood routine in which “we would spend Sunday afternoons down there just embracing the spiritual and spending time as a family.”

The primary contention encapsulated in Lefebvre’s theory is that space is a social product. He contends that space is socially produced and based on the values and meanings societally and individually assigned. It represents space as an abstraction and conceived product of human negotiation, as a physical entity that can be perceived, and as a spatial medium in which lived interaction creates meaning (Gottdiener, 1993). The genius of Lefebvre’s theory is its applicability across space and time; the contention that every society has, and continues, to produce space. Both historic and contemporary space, such as the reservation, should be assessed not as a static, typecast moment of time, but as a dynamic production with its own set of complexities.

The volunteers, while likely unaware of Lefebvre’s theory, all carried motivation to participate that could be categorized into one or more aspects of the triad. It is not that learning about aquatic macroinvertebrates or gaining research experience is not motivation towards volunteering, but there are innumerable ways to achieve these goals if they acted autonomously. It was apparent there was something deeper that transcended the actions of the RRBSA itself and encapsulated the spiritual and emotional side of the volunteers. Even for volunteers who had never spent a moment in the reservation, just simply being in the out-of-doors was a far more concrete motivational factor than learning about aquatic macroinvertebrates or gaining research experience. This conclusion is perhaps best summed up by Gerald, who had never visited the reservation
prior to volunteering but understood, “The [reservation] is like a buffet and most poor bastards are starving.” Understanding this hunger the volunteers intrinsically possess and bring with them to a citizen science program is only the beginning. Regardless of how hungry the volunteers are, understanding that volunteers with no previous experience or knowledge in the domain are motivated and capable of executing citizen science program research means little without interaction and education. Each of these constructs, as this research has demonstrated, are capable of leading to a valid data set for the sponsoring and facilitating agencies and, more importantly, an elevated civic science literacy for volunteers through the renewed citizen science paradigm.

5.1.3 Temporally and Spatially Controlled Research

The renewed citizen science paradigm understands the inherent motivation that all American adults have to participate in scientific research, particularly those generating data capable of affecting their person, family, and/or community. However, the renewed citizen science paradigm also understands the intrinsic hesitation and avoidance American adults have when past experience, time, and economic solidarity trump any potential to participate; even when the motivation is an overwhelming factor. In creating a forum for nonformal outdoor adult education that caters to the philanthropic motivation and the goal of maximizing the civic science literacy elevation for the volunteer, the renewed citizen science paradigm addresses scientific issues on a more spatially and temporally controlled level. While many citizen science organizations would rightfully say that most of the research problems being addressed require a more spatially and temporally expansive level – one of the main tenets defining the necessity of citizen
science research – the renewed citizen science paradigm will later introduce a solution to this quandary.

Over the past two decades, citizen science has been a tool for soliciting the general public to collect valuable research data that would otherwise be spatially, temporally, and/or financially prohibitive to secure. Citizen science, state Cooper, Dickinson, Phillips, and Bonney (2007), “engages a dispersed network of volunteers to assist in professional research using methodologies that have been developed by or in collaboration with professional researchers…[and] The public plays a role in data collection across broad geographic regions” (p. 11). To use volunteers from the general public not only taps a tremendous pool of human resources in the acquisition of scientific data, but the apportionment of volunteers allows researchers to address ambitious problems without spatial or temporal boundaries. However, as a tool – as was demonstrated by the RRBSA – the renewed citizen science paradigm provides the necessary ductility to be molded towards more temporally and spatially controlled scientific purposes; later introducing a unique pyramidal docent scheme that enables more ambitious research problems to be addressed while maintaining the NOAE and experiential learning components.

Many of the citizen science programs that preceded the 2010 RRBSA were executed as temporally and spatially expansive projects; often utilizing the help of hundreds of volunteers covering hundreds to thousands of square miles. The Seed Preference Test program was applauded for its 5,000 citizen science volunteers, although they only constituted 29% of the 17,000 individuals who signed-up to volunteer for a program that lasted years and nearly covered the entire United States (Trumbull, et. al., 2000).
Similarly, the House Finch Disease Survey was a nationwide program and lasted more
than six years (Altizer, Hochachka, & Dhondt, 2004), one year of service less than that
expected from the 530 volunteers of the Birdhouse Network program (Cooper et al.,
2006). While these programs were unilaterally developed towards collecting data and
answering research questions that required spatial and temporal expansiveness, other
citizen science programs have demonstrated similar successes on either a more
temporally or more spatially controlled level. For example, the Migration Monitoring
program asked 104 volunteers to dedicate four hours a week for 10 to 15 weeks, but the
program was executed over 13 states and two countries over a total period of four years
(Hamel et al., 2005). The Tucson Bird Count was temporally constrained but asked each
of 150 volunteers to cover 10km² of space each. Road Watch in the Pass was executed
over 11 months with 58 volunteers (Lee, Quinn, & Duke, 2000), certainly temporally
constrained, but like the Tucson Bird Count and many other programs, was spatially
expansive for the individual volunteer. Perhaps the closest we come to spatial restraint is
the Neighborhood Nestwatch program in which 175 volunteer households were only
responsible for collecting data relevant to their own backyards (Evans et al., 2005).

The RRBSA, under the auspices of a renewed citizen science paradigm capable of
providing NOAE, was temporally and spatially controlled. For the 67 volunteers, the
total time commitment of each was approximately 16 hours over the course of four
months and the program incorporated 15 stream reaches covering only 23 river miles.
The temporal and spatial constraint of the RRBSA enabled NOAE to be an integral part
of the program. While the citizen science programs that preceded the RRBSA are
invaluable to the scientific community, it’s the expansiveness that omits any potential of
providing NOAE. Whereas these programs contend that educating volunteers has little to no bearing on the results of the citizen science project, or that they are providing education to the volunteers through print media or information access on the World Wide Web, the RRBSA demonstrates the invaluable nature of NOAE and volunteer interactions with the facilitating agency, sponsoring agency, and professional scientists towards the development of both civic science literacy and valid data. In some programs, such as the Seed Preference Test, volunteer data was not even evaluated for validity or correctness.

In addition to their intrinsic motivation, the general public’s appeal for scientific content knowledge often catalyzes their engagement in citizen science, particularly when a project is meaningful to them and expected to yield meaningful results. These meaningful programs are often those addressing local issues in a way that is in sharp contrast to formal science education, and what Trumbull et al. (2000) term “cookbook classroom laboratories” (p. 268). This contrast is shared by Cooper et al. (2007) who insinuate that volunteers have more to gain by being accompanied by professional scientists. But it is not just the presence of the scientists that counts - such as the passive interaction of scientists and volunteers in the Neighborhood Nestwatch (Evans et al., 2005) program, it is the interaction and cohesion of scientists and volunteers working as a team throughout NOAE and experiential learning under the veneration of andragogical principles in the renewed citizen science paradigm.

5.1.4 The Presence of Nonformal Outdoor Adult Education

The RRBSA epitomized the renewed citizen science paradigm in that it offered NOAE towards elevating the civic science literacy of the program’s adult volunteers.
The NOAE component not only brings together the volunteers and scientists involved in the program’s totality, it also served to facilitate experiential learning towards science process understanding; an important component of civic science literacy. The NOAE also revealed several secondary benefits that were not conceived prior to the research but emerged during the course of programming, benefits that included the development of a team network among volunteers and scientists, an absence of attrition, the sharing of data and research information towards enhancing civic science literacy, and an increase in the number of volunteers as the program progressed. However, none of these benefits could have been conceived without the incorporation of andragogical constructs.

Whereas knowledge transmission and transfer-of-learning can be executed in any number of educational forms, the adult volunteer characterizing the renewed citizen science paradigm must be viewed as a partner in research and not a child or a tool for research purposes. Towards meeting the primary goal of the renewed citizen science paradigm, the foundation of NOAE embraces the theory of andragogy. According to Knowles (1980), andragogy is “the art and science of helping adults learn” (p. 43), and carries the underlying ideology that adult learners possess attributes as learners that separate them from children. While andragogy as a principle of adult learning is “appropriate for all adults regardless of subject content, setting, or purpose,” state Pratt and Nesbitt (2000, p. 120), not all forums are congruent with experiential learning theories. One forum that does serve as the ideal converging ground for outdoor adult education, nonformal adult education, and experiential learning theory is the NOAE of the renewed citizen science paradigm. The renewed citizen science paradigm and its NOAE takes andragogical considerations into account at all stages of the process.
beginning with the acknowledgement of the volunteer nature of learning for adults and the worldview of each learner; a learner, elaborates Merriam, Caffarella, and Baumgartner (2007), “who is autonomous, free, and growth oriented” (p. 88).

The RRBSA and the renewed citizen science paradigm necessarily understood the six assumptions about the adult learner that andragogy is based on, assumptions that “characterize adult learners and have formed the basis for structuring learning activities with adults,” state Merriam and Brockett (1997, p. 15). These assumptions, synthesized from Knowles (1989), include the following: 1) unlike many children, adults are intrinsically motivated to attend learning activities; 2) adults are different from children in that they are more “life centered” (problem- or task-centered) in choosing to participate in educational programs; 3) before partaking in any educational activity, adults must know why or how the content of the program is important for them to learn; 4) adults come to the classroom ready to learn; 5) adults need to be viewed and respected as learners capable of self-direction; and, 6) adults bring with them a richer volume and understanding of their personal experiences to the learning program. These assumptions are foundational for all organizations developing, implementing, and evaluating learning programs for adults (Merriam, Caffarella, & Baumgartner, 2007), and is essential in creating successful NOAE in the renewed citizen science paradigm.

In expounding on Knowle’s andragogical assumptions, the role of the renewed citizen science program staff serving as educators must be transformed to that of “facilitators” (Eisen, 2005; Merriam & Brockett, 1997; Merriam, Caffarella, & Baumgartner, 2007; Pratt & Nesbit, 2000) and partners. The NOAE staff listened to the volunteers in developing NOAE programs that addressed the volunteer’s needs (both personally and
towards the research) and developed learning environments that proved to be climates of adulthood in which the traditional teacher-student relationship is transformed to one of facilitator-learner collaboratively working towards common goals (Merriam, 2001).

In addition to understanding the intrinsic motivation of volunteers and developing a temporally and spatially controlled renewed citizen science program that addressed more “life-centered” scientific issues, the RRBSA facilitating agency took the time to communicate with volunteers the goals, the type of data, and the curricular activities to be executed prior to the program’s June 13th orientation. By relaying this information in advance, a task performed via e-mail and through the communicative interaction of facilitating scientists and potential volunteers, the volunteers were given the ability to assess their interest, time availability, and the centric nature of the research in their own life. In addition, the interaction of volunteers and scientists laid the foundation for enhanced motivation, a feeling of importance in the research, and a level of comfort in catalyzing a team atmosphere; all factors believed to account for the lack of attrition. By the time volunteers arrived at the RRBSA orientation session, they already felt comfortable and began interacting with each other and sharing personal accounts and concerns; they were ready to learn.

Adults also need to be viewed and respected as capable of self-direction, a critical aspect of experiential learning within the renewed citizen science paradigm. As was discussed by Coleman (1977), experiential learning cannot be disconnected from some form of classroom education. These classrooms can be traditional formal educational settings, as was demonstrated by Blunsdon et al. (2003), nonformal educational settings with didactic instruction (particularly for K-12 students and continuing professional
education), or the renewed citizen science paradigm’s NOAE forum where a
nonhierarchical classroom consistently acted and reacted to moment-by-moment
dynamics and general volunteer interests and concerns that helped shape and
metamorphose the curriculum as it progressed.

NOAE, explored and defined in this research to demonstrate its ideal position in
experiential learning and the renewed citizen science paradigm, relies on classroom
instruction to educate volunteers on the research topic. This adaptation within NOAE
allows the maximum audience to be reached; often with those lacking content knowledge
bringing an often-unexpected advantageous aura that positively affects the whole group.

In reviewing an experiential learning project and addressing this point, Rosenberg (2007)
states, “Prior to the session, participants knew very little about what they were about to
experience. This fueled anticipation and excitement” (p. 27). Any way one envisions the
knowledge transfer process through experiential learning theory, there is never a
complete disconnect from the educational forum. To do so would be to eliminate the
importance of context preceding, during, and following the experience. “Knowledge
produced through aesthetic experience,” Barrett (2007) reminds us, “is always contextual
and situated” (p. 115). In recognizing the context of the individual experience, NOAE
throughout the RRBSA served many roles beyond scientific education and the facilitation
of experiential learning; it served as a place to share actions, scientific understanding, and
developments towards generalization. In addition, the RRBSA forum targeted
maximizing the volunteer’s knowledge acquisition relevant to compounding field results
and individual concerns in the development of civic science literacy.
Experiential learning theory is deeply rooted in both cultural and philosophical traditions and has been employed for centuries as an essential framework for effective adult learning. While many variations of the theory circulate, Coleman’s (1977) experiential learning theory sets forth a succinct, four-step, guiding framework that is universally applicable within a renewed citizen science paradigm targeted towards elevating the civic science literacy of volunteers. In challenging the traditional role of citizen science programs, experiential learning not only enhances the field experience but provides a foundation for the assertion of civic science literacy in social and democratic forums. The RRBSA embraces Coleman’s theory and recognizes, as stated by Walter and Marks (1981), “Experiential learning is above all an action approach to change” (p. 151).

The first step of Coleman’s (1977) framework is immersion - leading students into the outdoors to act on the environment of study. When citizen science programs fail to execute this first step, the ability of citizen science to elevate the civic science literacy of adult volunteers is compromised. The renewed citizen science paradigm, and its execution during the RRBSA, understands this tenet and scientists from the sponsoring and facilitating agencies took the volunteers into the field during the orientation. The immersion of the volunteers introduced them to experiential learning through the guided execution of the research protocols, as well as introducing the volunteers to a number of aquatic macroinvertebrates in their natural environment, fluvial dynamics, and an array of scientific processes taking place. The action of volunteers during their immersion is the most fundamental doctrine of experiential learning and serves as the individual’s path towards cognitive growth, a commitment to study, continued experience, and, ultimately,
an overall elevation of civic science literacy. During the initial action process, the facilitating scientist’s goal was to guide the adult learner towards “A novel experience,” which according to Cheung (2006, p. 75), “will trigger more learning.” The RRBSA not only introduced the volunteer’s senses to the out-of-doors environment of study, but it introduced the volunteer to “novel” subject matter and dynamics that challenge the volunteer’s previous held beliefs. This transformational moment served as a catalyst for continued participation and discourse both within and beyond the program itself – the foundation for civic science literacy assertion that evolved as a result of participation.

In the second step of Coleman’s framework, reflection, volunteers of the renewed citizen science paradigm were taught to reflect upon the consequence(s) of their action; critically reflecting towards both understanding the effects of their action within a particular context and developing knowledge relevant to building science process understanding and generalizability, the third and fourth steps, respectively, of Coleman’s framework (Coleman, 1977). While the facilitating scientists are removed from the reflection stage, the NOAE sessions encouraged discourse among participants as a means of enhancing reflections and the totality of the experience. As the volunteer’s actions expanded during the RRBSA, the effects and personal understanding of those effects began to converge and create a concrete systemic understanding; an emerging structure phase demonstrated through both the quantitative and qualitative methods that is easily attributed to the renewed citizen science paradigm programming.

With understanding and generalization needed to follow in kind, the RRBSA spent several sessions discussing the foundation of the scientific method. Volunteers of the RRBSA renewed citizen science paradigm were reminded at all phases that
generalization can only occur with experience. The volunteer must freely choose to test and retest their hypotheses regarding their action, a time-based tenet that is aligned with positive development and proximal processes (see Bronfenbrenner, 1999); distinguishing the effects of multiple actions across experiences. After procuring the ability to successfully hypothesize the effects of differing action and the combination of that action within a dynamic environment – through multiple immersions throughout the RRBSA - the learning process expanded and the volunteers began to arm themselves with a unified understanding of principles that were reciprocally useful during their assertion of civic science literacy in social forums within a scientifically evolving democracy.

5.2 Maintaining the Basic Tenet of Citizen Science: Data Collection and Veracity

For over a century, scientists within academia and other professional, scientific organizations have called on the general public to collect valuable research data. But for some observers of citizen science programs, including David Ucko, the director of the National Science Foundation’s Division for learning (as cited in Cohn, 2008), “Our objective is to increase public awareness of and participation in science….we are more interested in the educational values than the research results” (p. 193). In accordance with Ucko, reinventing citizen science towards the elevation of civic science literacy of adult participants and their assertion of their new found civic science literacy is the primary goal of the renewed citizen science paradigm. However, the most fundamental tenet of citizen science, and the renewed citizen science paradigm alike, is the efficient collection of veracious data for the targeted good of answering scientific questions posed by scientific institutions, the scientific community, and/or the community-at-large. By executing the renewed citizen science paradigm under the guise of the scientific method,
the RRBSA maintained the basic tenet of citizen science without intimidating or reifying
the volunteer as little more than a research tool.

Over a period of four months from June 15th to October 15th, 2010, the RRBSA
volunteers, working in teams of two or more, made over 100 reach visits, covering 23
river miles, and collected over 30,000 pieces of data. Of prime importance to ODNR, the
sponsoring agency, the facilitating agency, and the reservation director was the
unprecedented identification of over 20,104 aquatic macroinvertebrates taxonomically to
order. All data was assessed for validity by the sponsoring agency’s aquatic research
coordinator, director - an aquatic biologist – as well as a team of additional natural
science researchers. While meeting the civic science literacy goals of the renewed citizen
science paradigm, the RRBSA also accumulated more data, and more useable data, than
the sum of the preceding RRBSA programs. The data was found to have a high degree of
internal and external validity; making the data, according to the director of the sponsoring
agency, “admissible in a court of law, for the acquisition of easements, land management
policy initiatives, and for the procurement of grants” (personal communication, October
27, 2010) among other actions that may be taken. The RRBSA clearly demonstrates how
a renewed citizen science paradigm can meet the resounding result of elevating volunteer
civic science literacy while collecting meaningful and veracious scientific data for
institutionally-based scientific research.

5.3 Conducting More Expansive Research: A Pyramid Schemed Docent Component

Many of the institutions executing citizen science programs do so out of necessity.
The ability to deploy thousands of researchers, for years at a time, citizen science
certainly has a measurable role in addressing temporally and spatially expansive
scientific research. To use volunteers from the general public not only serves as a tremendous pool of human resources towards the acquisition of scientific data, but the apportionment of those volunteers allows researchers to address spatially ambitious research problems. As has been discussed, one of the many changes and advantages of the renewed citizen science paradigm is the temporally and spatially controlled nature of the research. But when research requires a much more expansive range of space and time to properly address the scientific question(s), the renewed citizen science paradigm offers an innovative solution without compromising its foundation.

As a field of professional practice, scientific institutions have generally perpetuated a disconnect between institutional and general populace interests; ignoring the professional and intellectual contributions that our nation’s citizenry can make in advancing scientific knowledge and assisting institutions (e.g. past professional and personal experiences in thousands of domains, the level of localized expertise they bring to a project, their maturity and willingness to work with integrity towards meeting larger research scientific goals that affect our nation and its communities, etc.). Whether clearly defined or not, traditional citizen science programs have helped to bridge that gap, but continue to disregard one the most valuable of the volunteer’s motivation – the desire to comingle, communicate, share, teach, and learn. Capitalizing on these desires, the pyramid-schemed docent network of the renewed citizen science paradigm utilizes volunteers to interconnect spatially and temporally controlled research into a cohesive, expansive, and singular project, without temporal or spatial constraint, facilitated through a central scientific institution. But who are these volunteer docents?
For many older adults, as discussed by Freedman (as cited in Eisen, 2005, p. 22), there is “a growing movement of retired professionals who are…not content to embrace the ‘golden years’ notion of leisure, recreation, and disengagement…[they seek] greater meaning, stimulation, and the chance to make a difference” (p. 22). With 76 million baby-boomers having met or approaching retirement with uneasiness towards filling their time outside of their standardized routines, the time is now for academic, professional, and government agencies to recognize the value of adults and retirees willing to provide their time, without financial remuneration, to help address emerging scientific issues, learn the science related to them, and become docents within a greater docent scheme.

While many non-profit institutions rely on volunteers to fill basic roles within the organization, museums – including zoos and parks, among other science-centric institutions - have long relied on docents towards providing information-rich education. The use of docents has become an integral, and some might argue necessary, aspect of organizations operating under the umbrella of financial constraint. Today, states Robin Grenier (2009) “Docents are the most widely used educational service in today’s museums, making their work critical to the success of U.S. Museums” (p. 143). But being a docent is not just a matter of signing up. According to Nancy Howell, the docent program director at the Cleveland Museum of Natural History (CMNH), “The American Association for Museums has standards for all aspects of museum operation, including strict guidelines for the use and participation of docents” (personal communication, July 8, 2007).

With an annual operating budget of only $1750-$2000, the CMNH turns away nearly 100 successful docent candidates each year to concentrate on a more manageable cohort.
of 20 candidates; of which, on average, only 12 will become docents. The successful docent graduates are required to work regular hours at the CMNH and/or one of its satellite locations, without payment or benefit, for a minimum period of one year. In addition, docents – who average 65 years of age at the CMNH - are required to attend monthly continuing education programs; programs often led by more tenured docents. For many organizations, including the CMNH, docents develop a tenure-based structure, or “docent council,” as discussed by Grenier (2009, p. 143), of leadership, mentorship, and continuing adult education.

While there is much work to be completed, this research recognizes the need for spatially and temporally expansive research and offers the foundational framework for addressing the quandary of meeting both the scientific and educational goals of a renewed citizen science paradigm. The pyramidally-schemed docent component – “pyramidal” from a geographic perspective enabling localized research to evolve into more expansive, structured networks addressing scientific issues on a larger scale – expands on the successes of the traditional docent council of American museums. American adults, including 76 million baby boomers, are motivated, eager, and capable of meeting the challenges of institutionally-based expansive scientific research goals as researchers, facilitators, educators, mentors, collaborators, and institutional liaisons. The track record of docents as competent, collaborative leaders may actually have the potential to lift the human capital onus from sponsoring and facilitating agencies involved in citizen science programming; freeing up valuable resources within those agencies for important data analyses and literary contributions to the wider scope of scientific literature.
CHAPTER VI
CONCLUSIONS

The average American adult’s understanding of science is less than desirable (Mervis, 2007; Cetron & Gayle, 1991; Ruvinsky, 2007; Jenkins, 1997); with only one in four American adults considered scientifically literate (Brainard, 2008). As our globally expanding society becomes increasingly embedded in science and technology that both affects individuals and contributes to the overall public welfare of American society, there is an important need to improve the civic science literacy of the adult populace. This research set out to solve the civic science literacy problem by identifying both a forum and a learner-centric method of education capable of elevating the science vocabulary and science process understanding of participating adults. Serendipitously, I was thinking about this problem on a cold March afternoon while out in the field, as a citizen science volunteer, collecting data on amphibian reproduction when it occurred to me that what I was doing was the answer. Citizen science was the ideal forum, but a review of the literature identified two important components that were absent from citizen science for building civic science literacy: a) a specified goal to improve the participating volunteer’s scientific vocabulary and understanding of scientific processes through adult-oriented educational programs; and, b) nonformal education - an
“organized, intentional and explicit effort to promote learning to enhance the quality of life through non-school settings,” as defined by Joe Heimlich (1993, p. 2), towards educating and enhancing experiential learning. This was not a surprise given that the traditional citizen science program I was volunteering for did not offer any education or science mentorship; you were expected to bring the necessary knowledge and skills with you to the program.

This research was born through the recognition of a problem, an imperfect solution, and a host of literature towards reinventing what citizen science can be. Whereas there was little doubt that civic science literacy could be a resounding result of citizen science programs, there was a failure of creative suggestions as to how the citizen science volunteer is to acquire civic science literacy through their involvement in institutionally based scientific research. The renewed citizen science paradigm addressed these shortcomings and, through its introduction and execution in this research, successfully expanded the epistemological foundation of volunteers through the traditional citizen science program redesigned to incorporate nonformal outdoor adult education and the facilitation of experiential learning towards marked elevations in the civic science literacy of volunteers. The mergence not only maintained the basic tenets of citizen science programming towards the acquisition of useful data in addressing scientific problems, it successfully elevated the civic science literacy of adult participants and elucidated how such elevations led to an assertion of that knowledge in social forums within a scientifically evolving democracy. This assertion was unsolicited and prepared volunteers to discuss the research content and findings in an intelligible and cohesive manner congruent with mainstream science. In addition, the renewed citizen science
paradigm’s incorporation of spatially and temporally controlled research employing the renewed citizen science paradigm was able to maintain the basic tenets of citizen science and demonstrated how an expansive data set with both validity and applicability towards addressing more salient scientific issues emerged.

6.1 Filling the Gaps

This research made marked steps in not just understanding the failure of America’s adult’s to keep pace with scientific knowledge and systematic advancements in the science (Mervis, 2007; Cetron & Gayle, 1991; Ruvinsky, 2007; Jenkins, 1997; Freedman, 1997; National Research Council, 1996; Cavallo & Laubach, 2001; Stake & Mares, 2001; Jones, Howe & Rua, 2000; Meyer, 1998; Hornung, 1987), but it developed a creative, innovative, workable, and efficient solution to the problem with adult learners in mind. The rhetoric is no longer that educational researchers must understand why America’s adult citizenry is civic science illiterate and evasive of science content, it is in determining best-practice approaches to enable citizens, as supported by Jenkins (1999), “to contribute to decision-making about issues that have a scientific dimension, whether these issues be personal…or more broadly political” (p. 703). By recognizing the emerging enthusiasm, motivation, and andragogical needs of adult’s towards successful elevations in civic science literacy - and drawing on the established literature base that has addressed issues of formal education stigmatization and science aversion - the renewed citizen science paradigm methodology clearly indicates how civic science literacy elevations can be achieved. This methodology, as outlined in the renewed citizen science paradigm, is executed on behalf of adults seeking civic science literacy and greater voice and actability in a scientifically evolving society; in the right context, with
the right constructs, towards a more pervasive presence of civic science literacy among American adults.

This research also recognized the foundational problem of traditional citizen science programming, which seeks to collect data on temporally and spatially expansive levels, towards making education a program goal. The renewed citizen science paradigm enables citizen science programming to be executed on a more spatially and temporally restricted level; a construct that enabled scientists and volunteers to work together. As discussed in the introduction to this work, scientists teaching science is not a novel idea. Museums, zoos, parks, expositions, and other out-of-classroom science-based forums have been successfully serving both the scientific community and the greater populace of those seeking education for centuries. By replacing the passive print media and websites of traditional citizen science programming with real scientists, the participants of the RRBSA expressed how this relationship empowered them to learn and perform; gaining civic science literacy and collecting an exceptional data set of over 30,000 pieces of data. The relationship of citizen science sponsoring institutions and the citizen science volunteer within the renewed citizen science paradigm becomes very simple; recognize that while “institutions make things possible,” states Zahariadis (2007, p. 84), “people make things happen.”

Of course the primary goal of citizen science is not education; it is the collection of data towards addressing ambitious research problems. Towards meeting this goal – an important aspect of the renewed citizen science paradigm – the research explored and offered an innovative solution through the creation of a pyramid schemed docent component that maintains the educational foundation of the renewed citizen science
paradigm while meeting the basic tenet of widespread data collection of traditional citizen science programs.

6.2 Recommendations for Future Research

6.2.1 The Renewed Citizen Science Paradigm and Critical Theory

One aspect of future research is to study the effectiveness of the renewed citizen science paradigm towards arming volunteers with the ability to not only assert their civic science literacy, but coalesce and act, within an evolving science-based democracy. Cooper et al. (2007) have suggested making significant strides in educating volunteers towards more broadly social outcomes through citizen science. Such a transition is aligned with critical theory, such as participatory action research, as included in citizen science programs executed in the United Kingdom (UK). While the presence of citizen science programs in the UK is not as wide-spread or historically driven as it is in the United States, UK citizen science researcher E.W. Jenkins (1999) believes that citizen science is best executed when the science “relates in reflexive ways to the concerns, interests and activities of citizens as they go about their everyday business (p. 704).” From this more socially defining perspective of citizen science, Jenkins makes it clear that for most citizens, their interests in science - including those topics for which they elect to volunteer in research - is directly linked with decision-making and preparing for social action. While not whole-heartedly supported by this researcher, the renewed citizen science paradigm could be employed to align science and anticipated movements towards change with volunteers that are the proponents of the emerging political ideology of the movement (Jenkins, 1999). My only hesitation in fully supporting this idea is in insuring that the paradigm is properly used to acquire and advance good, objective
science; not misguided special interests or corporate corruption. As discussed by Holling (1998, p. 4), “theories, different modes of inquiry, and different rules of evidence can facilitate, hinder, or destroy the development of constructive policy and action.” The emerging creed within this application of the renewed citizen science paradigm would become very simple, recognize that while “institutions make things possible,” states Zahariadis (2007, p. 84), “people make things happen.”

Critical theory research (CTR) represents the broader umbrella of research designed to empower citizens to change their personal and social contexts (Merriam, 2002). According to Tisdell (2002, p. 91), “The term critical means two things in research: (1) dealing with and challenging power relations (as in critical theory or critical pedagogy), and (2) facilitating some sort of action among participants while the study is going on.” The practice of adult education during the latter half of the twentieth century has metamorphosed from a social practice ingrained in civic engagement and democracy to, as Thomas Heaney (2007) states, a practice designed for “molding citizens to pre-existing social conditions (p. 566).” As Heaney views it, albeit a bit facetious, the practice of adult education has transformed adult learners into hamsters living “an exhausting and debilitating life on a treadmill…running faster and faster to maintain a relatively stable position” (p.566). To no uncertain degree, the notion of adult education for social and political purpose, especially those issues requiring some degree of scientific literacy, has gone by the wayside and now caters to individuals willing to conform to institutional interests.

Creating an adult citizenry armed for participatory action research requires the renewed citizen science paradigm to complement traditional top-down scientific inquiry
with bottom-up exploratory and scientific research. Unlike the institutions commonly supporting geographically expansive citizen science projects, state Burke, Estrin, Hansen, Parker, Ramanathan, Reddy, and Srivastava, (2006), “Citizens have intimate knowledge of patterns and anomalies in their communities… enabling them to respond is both empowering and valuable to long-term research.” There remain many politically-centered scientific issues, including those that are more spatially and temporally contained, that would benefit from citizen science programming. It is the future citizen science volunteer, the eyes and ears of their local community or region of recreation, which has the greatest ability to identify issues and natural dynamics requiring scientific investigation. Should the issue become more political or worthy of participatory action research, volunteers can make all data results available to the local citizenry towards improving their capacity to respond and react. The melding of bottom-up with top-down inquiries may also serve to broaden the intersection of the scientific community, particularly academic scientists, and the broader scientific knowledge of a collective citizenry. “The subspecialization typical of academic scientists,” states Brainard (2008, p. A10), “means that some are often surprisingly unfamiliar with foundational ideas outside their own fields (Brainard, 2008, p. A10).”

6.2.2 Expanding the Scientific Domains of Study

A second area of future research is to address the effectiveness of the renewed citizen science paradigm and citizen science programming in science domains beyond the natural sciences. As volunteers, citizen scientists offer their time without financial or material retribution, an unselfish trait of citizen scientists who “desire to help out in an authentic research project,” state Evans et al. (2005, p. 590), and have a chance to
contribute to the larger works of scientific literature and advanced scientific understanding. According to Cohn (2008), “citizen scientists are typically people who care about the wild, feel at home in nature, and have at least some awareness of the scientific process” (p. 195). Citizen science has been demonstrated on numerous occasions to be particularly effective for ecological research and monitoring (Cohn, 2008), but the renewed citizen science paradigm provides the necessary ductility to be molded towards specific purposes and, state Lee, Quinn, and Duke (2006), “complements and enhances more conventional scientific studies” (p. 2). “At a general level,” states Jenkins (1999, p. 706), “surveys suggest that in most industrialized countries, adults are more interested in, and more attentive to, medical and environmental rather than other scientific matters.” But how do we involve the general adult citizenry in medical research?

One solution to this may involve the integration of the renewed citizen science paradigm within experiential learning research, such as the advanced cardiac life support training (Kidd & Kendall, 2006) and pediatric residents and disabled children (Sharma, Lalinde, & Brosco, 2006) discussed in the literature review. While these programs are not intrinsically citizen science programs from the standpoint that members of the general citizenry can participate in the collection of data, they are forums where a renewed citizen science paradigm may be more effective over current approaches. Just as Dreyfus and Dreyfus suggest (as cited in Mott, 2000, p. 27), “practitioners learn in the context of practice and develop their skills according to a progression from novice to…expert.” This foundation of continuing professional adult education, particularly when data is being collected from practitioners towards best-practice methods, or improving public
outlook on a field of practice, may be best addressed by the renewed citizen science paradigm.

The medical field is also quite expansive and includes two very salient subjects of scientific interests among the general adult citizenry: dietary and exercise science. With the media-driven bombardment of euro-centric self-imagery and the thousands of weight lose and personal health products available on the market, organizations such as Consumer Reports and the Better Business Bureau have become mainstays for keeping the American public informed. However, these organizations are consumer protection agencies and not research-based scientific institutions. The renewed citizen science, particularly when coupled with the pyramidal docent scheme, can serve as an ideal forum for increasing the civic science literacy of volunteers in these domains while executing both short-term and long-term longitudinal studies. The value of this research would not only insure an unbiased sample of volunteers from the American population, but it may have a far-reaching impact on consumer spending in a scientifically evolving democracy where Americans spend $60 billion dollar in the diet and weight loss markets (Marketdata, 2010).

6.2.3 Potential for Pyramid Schemed Docent led Programming

A final area of future research involves the potential and effectiveness of a pyramid schemed docent component. One of the many changes and advantages of the renewed citizen science paradigm is the temporally and spatially controlled nature of the research. However, when research requires a much more expansive range of space and time to properly address the scientific question(s), the renewed citizen science paradigm offers the foundational workings of a pyramid schemed docent component towards executing
the research without compromising its basic tenet. For many older adults, as discussed by Freedman (as cited in Eisen, 2005, p. 22), there is “a growing movement of retired professionals who are…not content to embrace the ‘golden years’ notion of leisure, recreation, and disengagement…[they seek] greater meaning, stimulation, and the chance to make a difference” (p. 22). With 76 million baby-boomers having met or approaching retirement with an uneasiness towards filling their time outside of their standardized routines, the time is now for academic, professional, and government agencies to recognize the value of adults and retirees willing to provide their time, without financial remuneration, to help address emerging scientific issues, learn the science related to them, and become docents within a greater docent scheme. Today, states Grenier (2009) “Docents are the most widely used educational service in today’s museums, making their work critical to the success of U.S. Museums” (p. 143); they are the ideal stepping stone for networking temporally and spatially controlled citizen science programs.

As mentioned by Mrs. Howell of the CMNH, even a small staff of docents requires an operating budget in the range of $2000 annually; approximately $100 dollars per docent. In creating a network of docents, “a docent council,” as discussed by Grenier (2009, p. 143), could run citizen science program budgets into the tens of thousands of dollars depending on the research being addressed. One way to offset this expense may be to forward the cost of training to the docent themselves. According to Giving USA, a publication of Giving USA Foundation (2009), American’s donated over $300 billion dollars in 2008, with over $230 billion coming from individual donors. While religion remains the dominate target of individual donations (35% of annual total), education, the environment, and public-society benefit totaled $71.40 billion; even within the “worst
economic climate since the Great Depression,” states the Giving USA Foundation.

Asking docents to cover their own operating expense may seem a daunting proposition, but, when approached in a judicious manner, docents are exactly the type of individuals willing to make those donations – particularly to nonprofit organizations centered on education, the environment, and public-society benefit. In fact, with a developed civic science literacy leading to personal assertions towards the ownership of research data, docents may be willing to donate more towards remediation, conservation, and environmental stewardship.

While the semantics of planning a docent council may be capable of being outlined and surveyed for potential effectiveness, executing a large-scale citizen science program under the facilitating, network control of docents within the renewed citizen science paradigm remains untested. But what is known is that American adults, including 76 million baby boomers, are motivated, eager, and capable of meeting the challenges of institutionally-based expansive scientific research goals as researchers, facilitators, educators, mentors, collaborators, and institutional liaisons – as docents.
REFERENCES


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APPENDIX
APPENDIX A

CODING SCHEMATIC REPRESENTING THE PROGRESSION OF CIVIC SCIENCE LITERACY THROUGH THE RENEWED CITIZEN SCIENCE PARADIGM
## APPENDIX B

**OHIO DEPARTMENT OF NATURAL RESOURCES STREAM QUALITY MONITORING ASSESSMENT FORM**

River Mile ______ River Name __________________ Date ______ Season ______

Location ____________________________________________

County __________________ Township/City ________________

Person/Group Name ___________________ Number of Participants ______

Leader Name __________________________ Phone ___________________

Address ______________________________ Email _____________________

City __________________ Zip Code ____________

### DESCRIBE WATER CONDITIONS

<table>
<thead>
<tr>
<th>Water Conditions</th>
<th>Reading</th>
<th>Reading</th>
<th>Avg. of Readings</th>
<th>TSS (mg/l)</th>
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<tbody>
<tr>
<td>Color, odor, biovolume, surface, etc.</td>
<td>#1</td>
<td>#2</td>
<td></td>
<td></td>
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### PHYSICAL MEASUREMENTS

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<tr>
<th>Physical Measurement</th>
<th>Value</th>
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<tr>
<td>Width of Riffle (feet)</td>
<td>______</td>
<td>slit ____% gravel (25-2&quot;) ____% boulder (&gt;1&quot;) ____%</td>
</tr>
<tr>
<td>Length of Riffle (feet)</td>
<td>______</td>
<td></td>
</tr>
<tr>
<td>Water Depth (inch)</td>
<td>______</td>
<td>sand ____% cobble (2-1&quot;) ____%</td>
</tr>
<tr>
<td>Water Temperature (F)</td>
<td>______</td>
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</table>

### MACROINVERTEBRATE DATA

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<tr>
<th>Macroinvertebrate</th>
<th>Estimated Count</th>
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<tr>
<td>Group 1 Taxa</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Water Penny Larvae</td>
<td></td>
<td>Damselfly Nymph</td>
</tr>
<tr>
<td>Mayfly Nymph</td>
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<td>Dragonfly Nymph</td>
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<tr>
<td>Stonefly Nymph</td>
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<td>Cranefly Larvae</td>
</tr>
<tr>
<td>Dobsonfly Larvae</td>
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<td>Beetle Larvae</td>
</tr>
<tr>
<td>Caddisfly Larvae</td>
<td></td>
<td>Crayfish</td>
</tr>
<tr>
<td>Riffle Beetle Adult</td>
<td></td>
<td>Scud</td>
</tr>
<tr>
<td>Gillid Snail</td>
<td></td>
<td>Clam</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Snout</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Number of taxa</th>
<th>Number of taxa X 3 (Group 1 total)</th>
<th>Number of taxa X 2 (Group 2 total)</th>
<th>Number of taxa X 1 (Group 3 total)</th>
</tr>
</thead>
</table>

### CUMULATIVE INDEX VALUE (Sum of group 1,2,3 totals) =

Stream Quality Assessment Rating:

- Excellent (>22)
- Good (17-22)
- Fair (11-16)
- Poor (<11)
APPENDIX C

SELF REPORT SURVEY INSTRUMENT

Self-Report Survey: Part One

Instructions: In each row you will find a scientific term related to the 2010 Rocky River Biomonitoring Stream Assessment Citizen Science Program. Please read the term and then carefully reflect, as honestly and objectively as possible, on your knowledge of that scientific term BEFORE participating in the Rocky River Biomonitoring Stream Assessment. To the left of each term, there is a series of four numbers (0, 1, 2, and 3). After reflecting, please circle the ONE number that most closely represents your knowledge of the term BEFORE participation. The value of each response is as follows:

0 = I am unfamiliar with the term

1 = I have heard the term, but I could not tell you what it means

2 = I can verbalize what the term means, but not in a scientific manner and perhaps incorrectly

3 = I can verbalize the definition of the term in a scientific manner

After choosing the answer that most closely represents your knowledge of the term BEFORE your participation in the 2010 Rocky River Biomonitoring Stream Assessment Citizen Science Program, please move to the columns to the right of each term and circle the ONE number that most closely represents your knowledge of the term AFTER participation. The value of each response, similar to the previous instruction, is as follows:

0 = I have no idea / I never heard that term before

1 = I have heard the term, but I am unfamiliar with its meaning

2 = I can verbalize what the term means, but not in a scientific manner and perhaps incorrectly

3 = I can verbalize the definition of the term in a scientific manner

<table>
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<tr>
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<tbody>
<tr>
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<tr>
<td>0 1 2 3</td>
<td>Aquatic Macroinvertebrate</td>
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<tr>
<td>0</td>
<td>1</td>
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<td>---</td>
<td>---</td>
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<td>Stream</td>
<td>0</td>
</tr>
<tr>
<td>Reach</td>
<td>0</td>
</tr>
<tr>
<td>Ripple</td>
<td>0</td>
</tr>
<tr>
<td>Cobble</td>
<td>0</td>
</tr>
<tr>
<td>Naiad</td>
<td>0</td>
</tr>
<tr>
<td>Watershed</td>
<td>0</td>
</tr>
<tr>
<td>Larvae</td>
<td>0</td>
</tr>
<tr>
<td>Taxon</td>
<td>0</td>
</tr>
<tr>
<td>Dichotomous Key</td>
<td>0</td>
</tr>
<tr>
<td>Seine</td>
<td>0</td>
</tr>
<tr>
<td>EPT Taxa</td>
<td>0</td>
</tr>
<tr>
<td>Confluence</td>
<td>0</td>
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<tr>
<td>Cerci</td>
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<tr>
<td>Monoculture</td>
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<td>Bedgrowth</td>
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<td>Pollution</td>
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<tr>
<td>Substrate</td>
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<tr>
<td>Tannin</td>
<td>0</td>
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<tr>
<td>Turbidity</td>
<td>0</td>
</tr>
<tr>
<td>River Mouth</td>
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<tr>
<td>Drift</td>
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<tr>
<td>Insect</td>
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<td>Operculum</td>
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<td>Dextral</td>
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<td>Parasite</td>
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<tr>
<td>Pupation</td>
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<td>Holometabolus</td>
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<td>Mandible</td>
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<td>Tracheal Gills</td>
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<td>Bug</td>
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</tr>
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<td>Sessile Eyes</td>
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</tr>
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<td>Shredders</td>
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<tr>
<td>Umbo</td>
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<td>Hemimetabolus</td>
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<tr>
<td>Citizen Science</td>
<td>0</td>
</tr>
<tr>
<td>Prolegs</td>
<td>0</td>
</tr>
<tr>
<td>River Mile</td>
<td>0</td>
</tr>
<tr>
<td>Invertebrate Community Index</td>
<td>0</td>
</tr>
</tbody>
</table>
**Self-Report Survey: Part Two**

**Instructions**: In each row you will find a scientific process/dynamic related to the 2010 Rocky River Biomonitoring Stream Assessment Citizen Science Program. Please read the process/dynamic and then carefully reflect, as honestly and objectively as possible, on your knowledge of that scientific process/dynamic **BEFORE** participating in the Rocky River Biomonitoring Stream Assessment. To the left of each process/dynamic, there is a series of four numbers (0, 1, 2, and 3). After reflecting, please circle the ONE number that most closely represents your knowledge of the scientific process/dynamic **BEFORE** participation. The value of each response is as follows:

- **0** = I am unfamiliar with this process/dynamic
- **1** = I understand the process/dynamic, but I could not verbalize it to another person
- **2** = I can verbalize the process/dynamic to another person, but not in a scientific manner
- **3** = I can verbalize the scientific process/dynamic in a scientific manner to another person

After choosing the answer that most closely represents your knowledge of the scientific process/dynamic **BEFORE** your participation in the 2010 Rocky River Biomonitoring Stream Assessment Citizen Science Program, please move to the columns to the right of each scientific process/dynamic and circle the ONE number that most closely represents your knowledge of the scientific process/dynamic **AFTER** participation. The value of each response, similar to the previous instruction, is as follows:

- **0** = I am unfamiliar with this process/dynamic
- **1** = I know the process/dynamic, but I could not verbalize it to another person
- **2** = I can verbalize the process/dynamic to another person, but not in a scientific manner
- **3** = I can verbalize the scientific process/dynamic in a scientific manner to another person

<table>
<thead>
<tr>
<th>Before Research</th>
<th>After Research</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 1 2 3</td>
<td>0 1 2 3</td>
</tr>
<tr>
<td>Silt, Sand, Gravel, Cobble, and Boulder as scientifically defined metrics</td>
<td></td>
</tr>
<tr>
<td>0 1 2 3</td>
<td>0 1 2 3</td>
</tr>
<tr>
<td>Water Pennys attain their copper color from dietary conditions</td>
<td></td>
</tr>
<tr>
<td>0 1 2 3</td>
<td>0 1 2 3</td>
</tr>
<tr>
<td>Mayfly &quot;Nymphs&quot; are scientifically &quot;Naiads&quot;</td>
<td></td>
</tr>
<tr>
<td>0 1 2 3</td>
<td>0 1 2 3</td>
</tr>
<tr>
<td>The life stage of riffle beetle adults is entirely aquatic</td>
<td></td>
</tr>
<tr>
<td>0 1 2 3</td>
<td>0 1 2 3</td>
</tr>
<tr>
<td>The crayfish's exoskeleton hue is determined by diet</td>
<td></td>
</tr>
<tr>
<td>0 1 2 3</td>
<td>0 1 2 3</td>
</tr>
<tr>
<td>The motor action of aquatic worms as a means of differentiating their general identity from leeches</td>
<td></td>
</tr>
<tr>
<td>0 1 2 3</td>
<td>0 1 2 3</td>
</tr>
<tr>
<td>Leeches have two suckers for parasitic use (one posterior and one anterior)</td>
<td></td>
</tr>
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</table>

234
<table>
<thead>
<tr>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>I understand the respiratory difference between a lunged snail and a gilled snail</td>
<td>0</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Planaria are hemaphroditic and must split to reproduce</td>
<td>0</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Citizen Science relies on members of the community to collect scientific data</td>
<td>0</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Marcophyte interference in drift</td>
<td>0</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>My presence in the stream collecting aquatic macroinvertebrates is pollution</td>
<td>0</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>River miles; starting with river mile 0 at the mouth of a stream</td>
<td>0</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>I can calculate and explain the Invertebrate Community Index</td>
<td>0</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>The data you collected as part of this program could be used for easements</td>
<td>0</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>The difference between ephemeral and perennial stream dynamics</td>
<td>0</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>I can assess water odor and understand explain how this is done scientifically</td>
<td>0</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>I know that aquatic macroinvertebrates are in the stream year round and I can explain climatic variances</td>
<td>0</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>I understand why Biomonitoring is performed from June 15th to October 15th</td>
<td>0</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Leaf tannins not only change a stream water's color, but also its pH</td>
<td>0</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>I know the processes behind the proper use of a seine</td>
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<td>1</td>
<td>2</td>
</tr>
<tr>
<td>The difference between invasive species and a non-native species</td>
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<td>1</td>
<td>2</td>
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<tr>
<td>Snails as dextral or sinistral</td>
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<td>2</td>
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<tr>
<td>I understand why Biomonitoring is more effective compared to chemical analyses</td>
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<td>2</td>
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<tr>
<td>I understand why a reach is used in biomonitoring</td>
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<td>1</td>
<td>2</td>
</tr>
<tr>
<td>EPT Taxa members generally correlate to dissolved oxygen levels</td>
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<tr>
<td>Leeches can thrive in all oxygen level environments</td>
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<tr>
<td>Caddisflies use the labium to create nymph casings</td>
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<tr>
<td>There are 2000 different species of midges in North America</td>
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<td>Riffle beetle adults are a better indicator of water quality than their larvae</td>
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<tr>
<td>Crayfish, like their lobster relative, have 19 body segments</td>
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<td>Crayfish modified tarsals primary uses</td>
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</tbody>
</table>
Self-Report Survey: Part Three

Instructions: In each row you will find a scientifically based procedural skill related to the 2010 Rocky River Biomonitoring Stream Assessment Citizen Science Program. Please read the procedural skill set and then carefully reflect, as honestly and objectively as possible, on your knowledge of that scientifically based procedural skill BEFORE participating in the 2010 Rocky River Biomonitoring Stream Assessment. To the left of each procedural skill, there is a series of four numbers (0, 1, 2, and 3). After reflecting, please circle the ONE number that most closely represents your knowledge of the scientifically based procedural skill BEFORE participation. The value of each response is as follows:

0 = I was unfamiliar with how to execute this scientifically based procedural skill

1 = I knew the scientifically based procedural skill but could not have articulated/taught it to another participant

2 = I can articulate and teach the scientifically based procedural skill to another person, but not in a concise or scientific manner (proper use of vocabulary, system dynamics, etc.)

3 = I can articulate and teach the scientifically based procedural skill to another individual in a concise and scientific manner

After choosing the answer that most closely represents your knowledge of the scientifically based procedural skills BEFORE your participation in the 2010 Rocky River Biomonitoring Stream Assessment Citizen Science Program, please move to the columns to the right of each scientifically based procedural skill and circle the ONE number that most closely represents your knowledge and ability of the scientifically based procedural skill AFTER participation. The value of each response, similar to the previous instructions, is as follows:

0 = I am unfamiliar with this scientifically based procedural skill

1 = I know the scientifically based procedural skill but cannot articulated/teach it to another person

2 = I can articulate and teach the scientifically based procedural skill to another person, but not in a concise or scientific manner (proper use of vocabulary, system dynamics, etc.)

3 = I can articulate and teach the scientifically based procedural skill to another individual in a concise and scientific manner

<table>
<thead>
<tr>
<th>Before Research</th>
<th>After Research</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 1 2 3</td>
<td>0 1 2 3</td>
</tr>
<tr>
<td>I can properly assess the odor of a body of water</td>
<td>I can properly assess the odor of a body of water</td>
</tr>
<tr>
<td>0 1 2 3</td>
<td>0 1 2 3</td>
</tr>
<tr>
<td>I can properly assess the color of a body of water</td>
<td>I can properly assess the color of a body of water</td>
</tr>
<tr>
<td>0</td>
<td>1</td>
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