Curriculum Development for Water Chemistry Analysis:

Citizen Science in Rock Creek Park

An Interactive Qualifying Project
submitted to the faculty of
WORCESTER POLYTECHNIC INSTITUTE
in partial fulfillment of the requirements for the
degree of Bachelor of Science

By:

Melissa Galgano
Thomas McCarthy
Kevin O'Brien
John Perkoski

Date:
15 December 2017

Report Submitted to:

Ms. Maggie Zadorozny
Ms. Julia Washburn
National Park Service

Professor Scott Jiusto
Professor James Hanlan
Worcester Polytechnic Institute

Abstract

The goal of this project was to support the creation of a water chemistry analysis module for high school students that catered to various learning styles. To realize this goal, we researched educational programs, determined successful educational elements, and developed alternative learning modules. The project resulted in the development of a three-day curriculum that includes an introduction to the topic, videos demonstrating water chemistry tests, a workbook with procedures, and recommendations for data analysis and reflection. This project was sponsored by the National Park Service at Rock Creek Park and was co-developed with Montgomery County Public Schools and the Audubon Naturalist Society.

Executive Summary

The National Park Service (NPS) inspires students to become lifelong learners who appreciate the natural and cultural resources of the national parks. The parks offer hands-on, interactive field modules that supplement topics students learn in class by showing real-world applications. The NPS will introduce high school students to Rock Creek Park (ROCR) through citizen science. Citizen science is the art of using the public to quickly gather scientific knowledge (Bonney et al., 2009), while also engaging students in STEM education and promoting active citizenship, social justice and a healthy environment.

ROCR is located within the Washington, D.C. metropolitan area, and is an area of environmental concern. Rock Creek starts in Laytonsville, Maryland and flows south for 33 miles until it empties into the Potomac River. Most of the watershed is in a developed urban setting with more than half a million people in Washington, D.C. and lower Montgomery County (Rock Creek Conservancy: The Watershed, 2003). This section of the creek is susceptible to human impacts, such as urban runoff and pollution caused by a high population density and localized industrialization. In this area, the quality of water and aquatic life are consistently rated fair to poor, as opposed to good or excellent as found in the rural sections (Montgomery Department of Environmental Protection, 2017). The Downcounty Consortium, a partnership between five high schools in lower Montgomery County, aims to spread environmental awareness and literacy and engage students in the surveying of their watershed. The consortium obtained a National Park Foundation grant and will be partnering with ROCR and the Audubon Naturalist Society to provide a meaningful watershed educational experience for high school chemistry students. The program's design will empower the area's low-income minority youth to be aware of the impacts on their watershed and to develop the skills and insights necessary to inspire civic action. This project will provide thousands of students with a unique experience that educates them about human impacts on watershed quality.

Methodology

Through partnering with the National Park Service at Rock Creek Park and the Audubon Naturalist Society, Montgomery County Maryland Public Schools (MCPS) aims to establish a "meaningful watershed education experience" and to pique students' interest in science,

technology, engineering and math. This project resulted in the development of a three-day curriculum that includes an introduction to the topic, videos demonstrating water chemistry tests, a workbook with procedures, and recommendations for data analysis and reflection.

Ideas from existing citizen science watershed education programs were compiled, specifically from NPS, Hands on the Land, *Bridging the Watershed, Testing the Waters,* etc. Several chemistry field modules were observed at a stream near John F. Kennedy High School in Montgomery County, Maryland. The observations during this program served as the basis for in-class activities. We conducted a literature review of the NPS guiding principles, best practices, and goals for improvement. Existing programs were compared to the NPS guidelines. Findings were shared with stakeholders and colleagues to gather suggestions and recommendations.

We researched educational video games, websites, phone applications and videos as possible educational elements. Using principles from the previous section, we developed a method for integrating the chosen elements into the education component. The decision was made to create an interactive presentation with embedded videos to introduce the students to watershed quality, how-to videos for each of the water quality tests, and a workbook.

Project Outcomes

The MCPS high school chemistry curriculum includes a term-long project researching alternative-fuel vehicles. This project is ten weeks long with several subsections. The purpose is to connect energy and water by studying the effects of fossil-fuel emissions on the quality of local creeks and streams. MCPS has allotted three days (Figure 1*)* for the water quality curriculum, with each class being 45 minutes with 30 minutes of actual content. Day 1 introduces students to the topic, shows them its significance, engages the students and prepares them for the field module. On Day 2, students go to a creek or stream that is near their school and test the water using LaMotte test kits. On Day 3, the students analyze and share their data.

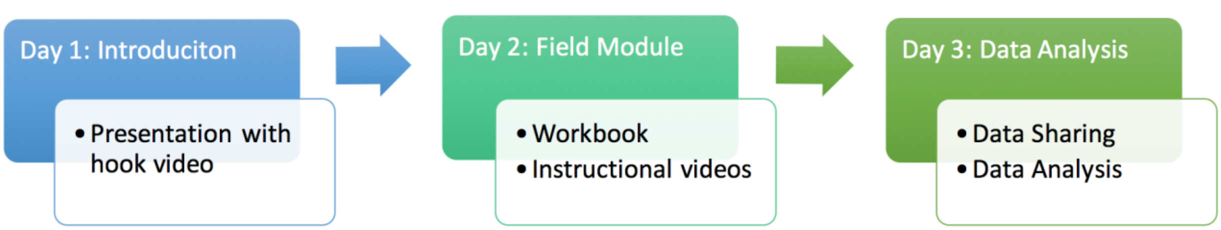


Figure 1: Three-Day Curriculum Outline

Prior to this project, MCPS had no successful introduction that engaged students with water chemistry. The stakeholders wanted curriculum that taught students the importance of water quality and wanted this be done through an interactive medium that tied water to energy. Students participated in a pilot field module in October 2017. The students were unfamiliar with the tests and what the significance of the data was. Therefore, the materials for Day 1 focus on addressing where the students get their drinking water and the significance of water chemistry analysis. Day 1 consists of an interactive presentation completed on Google Slides, a platform like PowerPoint that is used by MCPS. The presentation introduces students to water chemistry and includes time for discussion and videos.

During the project, four classes were observed at a pilot field module at a stream near John F. Kennedy High School. Students tested the waters at a local stream by analyzing temperature, pH, alkalinity, nitrates, phosphates, transparency and dissolved oxygen. It quickly became clear that improvements were needed to allow for a better learning experience. Most of the issues were related to time constraints and unclear instructions. To solve these problems, the number of tests were reduced to just dissolved oxygen, pH and nitrates. Deliverables for Day 2 include a workbook for students and revised procedures.

For Day 3, students will analyze their findings and compare results found during the field module. Students will compare data with other classmates, classes, and schools. They will find and explain discrepancies in their data as well as identify the pollutants that could be in their stream. The analysis can be a homework assignment, a reflection in the workbook, or a class discussion. Additionally, the recommendations include the adoption of a data sharing platform, such as CitSci.org which will allow students to complete these tasks.

Recommendations

1. Create a water quality index for analysis of stream quality

   Students and teachers should create a scoring system for stream health that considers all three water chemistry tests.

2. Establish a way for students to share data

   Students should have an online platform for data sharing that will help them understand and analyze stream quality in their county.

3. Have students research the county's storm water facilities and watershed health

   Students should investigate what measures the county is taking to address pollution and watershed health.

4. Further test the educational elements with students

   The stakeholders should continue testing and editing the program as issues arise.

5. Have opportunities for Student Service Learning

   MCPS should utilize Students Service Learners (SSLs) to broaden the scope of the project.

6. Establish independent learning environment for module

   The students should be able to navigate through the workbook and the assignments with little to no assistance from teachers.

7. Share educational elements

   The stakeholders should share the educational elements with other groups, such as other school systems in the DC Metro area, other national parks, and other watershed programs.

8. Expand module to be interdisciplinary

   Students could learn about other factors affecting their watershed and utilize their outdoor classrooms more frequently.

9. Expand program to other national parks

   The NPS could expand the program to other parks with the NPF grant to broaden the impact on students and watershed health.

10. Have a future WPI IQP team continue the project

    Next year, another IQP should continue working on this project with the stakeholders.

Table of Contents

Table of Figures

List of Tables

Chapter 1: Background

This chapter explains the significance of the National Park Service, specifically Rock Creek Park. It expands upon the project by reviewing the project's grant proposal submitted to the National Park Foundation. The NPF Grant introduces citizen science, the Next Generation Science Standards, project stakeholders, and the project timeline. This chapter also explores the importance of watersheds and watershed education modules. Finally, research is presented into how to engage students in citizen science.

1.1 National Park Service

The NPS is a U.S. government agency within the Department of the Interior with the goal of preserving America's natural and cultural resources for the enjoyment, education, and inspiration of citizens. The NPS educates citizens about the values of nature through educational programs and hands-on learning experiences. The NPS experiments with the best practices to regulate these educational programs (U.S. National Park Service, 2017). In this section, the history, mission and educational programs of the NPS will be discussed.

1.1.1 History of the National Park Service

Yellowstone National Park, the first national park, was founded on March 1, 1872. The formation of the NPS occurred on August 25, 1916. The NPS is engaged in the administration, management and control of national parks and monuments (Cameron, 1922).

The NPS has over 20,000 employees who share a passion for enjoying nature and sharing personal experiences. The Park Service is overseen by the U.S. Department of the Interior and is led by a director who is nominated by the President and confirmed by the Senate. The director is supported by senior executives who manage programs, policies, and budgets and seven regional directors who handle park management and program implementation (U.S. National Park Service, 2017).

The purpose of the NPS is to conserve natural and historic landmarks and monuments for the enjoyment of future generations (2017). The NPS has over 84 million acres of land used for the enjoyment and education of citizens. Over the years, the number of NPS visitors has grown from one million visitors in 1920 to 307 million visitors in 2015. In addition to employees, there are approximately 44,000 volunteers who help with the upkeep of NPS lands (U.S. National Park Service, 2017).

The NPS works in partnership with more than 150 non-profit organizations and 71 cooperating associations. Non-profit organizations support the education and outreach of national parks across the country. The non-profits and cooperating associations enhance the educational and interpretive experiences at the national parks. After celebrating its 100th anniversary in 2016, the NPS remains committed to its mission to preserve and protect the national parks for the enjoyment of all (U.S. National Park Service, 2017).

1.1.2 National Park Service Education Programs

Interpretation and education are part of the outreach mission of the NPS (U.S. National Park Service, 2003). Interpretation is the process of explaining parks and natural resources in a way that visitors can understand and relate to. Education means providing “all kinds of learning opportunities … including formal and informal programs, volunteer programs, lifelong learning, publications, exhibits, films, the Internet, public outreach, and research” (U.S. National Park Service, 2003). Through interpretation and education, the NPS invites citizens to become stewards and to help achieve its mission of protecting and preserving natural and cultural resources.

As laid out in the NPS report *Renewing Our Education Mission*, educational programs are “designed to enrich lives and enhance learning, nurturing people’s appreciation for parks and other special places, and therefore helping preserve America’s heritage” (2003). These programs use national parks as places where students can interact with tangible objects to allow for immersive, hands-on learning. Programs are to be learner-centered and cater to different learning styles while maintaining accessibility to all people. These ends can be encouraged through distance learning to allow for a broader audience. The guiding principles recommend celebrating diversity, taking various points of views, and incorporating sound scholarship content. In coordination with the overall goals of the NPS, a major guiding principle for an education program is encouraging participation in the United States’ civil democratic society. The guidelines recommend incorporating evaluation and collaboration to allow for the continued improvement of the programs (U.S. National Park Service, 2003).

1.1.3 Best Practices in National Park Service Education Programs

The NPS made important advances in education and interpretation during the 1950s when they developed an education training program for park rangers. This program led to the creation of several principles of interpretation. Overall, “the chief aim of Interpretation is not instruction, but provocation” (Mackintosh, 1986), meaning the desire to elicit a response from visitors, causing them to think critically. This philosophy is essential to the goal of the NPS, encouraging citizens to be lifelong appreciators of the national parks (Mackintosh, 1986).

Since the development of the initial training program in the 1950s, the education programs of the NPS have expanded greatly. Various best practices have been established to ensure that new programs continue to be developed and improve upon the lessons learned from other programs. The practices developed for interpretation are like those developed for education. When implementing education programs, training and networking resources need to be established (Bowling, 2013). In 2006, the NPS identified changes to implement to continue the success of education programs (U.S. National Park Service, 2006). The first major goal the report outlined was aligned with the overall goal of the NPS, calling for engagement between the community and America’s national parks. To accomplish this, the report recommends that “programs must be created in collaboration with communities and partners rather than for them” (U.S. National Park Service, 2006). Additionally, the report recommends the use of new technology, utilizing tools such as distance learning. This allows the department to engage with more students and create more accessible programs. Through collaboration with partner organizations, the NPS can utilize additional resources and perspectives. Bowling (2013) echoes this claim by recommending communication with other agencies and outside professionals. The NPS report also recognized that there is “very little scientifically valid information about the direct outcomes and impact of interpretation and education programs” (U.S. National Park Service, 2006). Overall, these goals and recommendations provide insight into the NPS’s aims for improvement.

1.2 Rock Creek Park

Rock Creek Park, located in northwest Washington, D.C., was established by Congress on September 27, 1890 for the recreational and scenic enjoyment of the people. ROCR is a naturally forested area in a highly urbanized region with over 300 acres of recreational facilities, roads, trails, structures and sites (Bushong, 1990).

In 1890, Congress gave the NPS a plot of land that was the original ROCR. In 1907, the Piney Branch Parkway was acquired by the government and added to the park. Today, ROCR contains many other urban parks, including Rock Creek Parkway, Normanstone Parkway, Soapstone Valley and Klingle Valley. These areas, acquired and integrated into the Washington park system between 1913 and 1950, were designed as access routes and as a means of preserving the Rock Creek Valley watershed (Bushong, 1990).

1.3 Chemistry Matters in Rock Creek

In June of 2017, the ANS, in conjunction with ROCR and MCPS, submitted a proposal to the National Park Foundation for the development of a high school chemistry water module. The ANS works to inspire citizens to appreciate their environment in the Washington, D.C. metro area. The National Park Foundation works in partnership with the NPS to enrich national parks and programs. In 2016, the foundation raised $126 million in support of national park projects and awarded 732 grants to 302 parks and public lands (National Park Foundation, 2016). The proposal is called “Chemistry Matters in Rock Creek Park: Citizen Science in the Rock Creek Watershed through Chemistry.” The proposal details the intended purpose of the NPF Grant, its stakeholders, and a project timeline (National Park Service, 2017). A major goal is to introduce students to citizen science, a method that has become increasingly popular with scientists to allow for the wide scale collection of scientific data by citizens that would not have been previously possible.

1.3.1 Chemistry Matters Grant Proposal

The National Park Foundation accepted the aforementioned proposal for the Chemistry Matters project. The proposal began after the signing of the 2014 Chesapeake Bay Agreement by the governors of the states within the Bay's watershed. The overall goal of the agreement is to have nearby states contribute to the restoration of the Bay and its tributaries. These governors are committed to implementing a program that gives high school students a meaningful watershed educational experience. No real attempts have been made to incorporate a meaningful watershed educational experience in high schools in Montgomery County prior to this proposal. The project itself aims to create a high school chemistry module to assist students in the study of watershed quality in ROCR and its watershed. The NPS hopes that engaging students in citizen science and introducing them to careers in the NPS will help students to develop a lifelong appreciation for STEM fields and the benefits that the national parks provide. The NPS hopes that this program can be used as a model for hands-on, field-based curriculum modules (National Park Service, 2017).

1.3.2 Citizen Science

Citizen science is utilizing the public to quickly gather scientific knowledge. Scientists receive information they would not be able to obtain themselves, and citizens have the satisfaction of contributing to a scientific observation (Bonney et al., 2009). The NPS plans to have MCPS students do research on the quality of the Rock Creek watershed. The students will go to Rock Creek, or another stream near their school, and test the water quality. The NPS's plan is for students to report their findings to their teachers, who will report back to the NPS. The NPS hopes that by exposing students to citizen science, it will interest them in STEM (Zadorozny, 2017). They know students may not enter a STEM career, but hope students will remain citizen scientists.

1.3.3 Next Generation Science Standards

This project will satisfy the Next Generation Science Standards (NGSS), "rigorous and internationally benchmarked science standards" (National Research Council, 2013), that were developed by 18 states and adopted by 26 states. The NGSS is designed to provide a "coherent progression of knowledge", providing a plan for a student's entire K-12 education that follows a logical path. The Chemistry Matters program will satisfy a portion of the NGSS as Maryland has adopted these standards and revised the Maryland Integrated Science Assessment to reflect them. These standards differ from previous attempts as they leave curriculum development to states and school districts. NGSS identifies three dimensions to measure science proficiency: practices, crosscutting concepts, and disciplinary core ideas. These three dimensions are combined when establishing each standard. Practices are the skills and methods used by scientists and engineers when conducting inquiries and experiments. Crosscutting concepts deal with those principles and approaches that are used in every scientific discipline. Some examples include pattern, similarity, and diversity; cause and effect; and scale, proportion and quantity. Disciplinary Core Ideas are topics that can apply to many disciplines, can be used for problem solving, "can be connected to societal or personal concerns" of the student, or can be expanded upon over multiple grades (National Research Council, 2013).

1.3.4 Chemistry Matters Project Outcomes

MCPS will be responsible for a significant amount of the core curriculum required to implement this project. To develop this curriculum, MCPS will obtain a deeper appreciation for the value of place-based learning through national parks. Montgomery County chemistry teachers must be confident in teaching the hands-on lessons. Furthermore, these lessons will be designed to meet environmental literacy standards included in the Next Generation Science Standards (NGSS). The hands-on learning will connect what students learn in the classroom to real-world applications that require problem-solving. This project will initially focus on high schools in the Downcounty Consortium, which includes five high schools and approximately 1500 chemistry students per year. These students will learn about the varied career opportunities with the NPS, including resource management and conservation. Students will see how science is used in people's careers and how science is used to drive policy decisions. This project will build a long-term relationship between the ANS, MCPS and NPS that will support field-based learning at the park for students in the county (National Park Service, 2017).

1.3.5 Stakeholders

The main stakeholders are the National Oceanic and Atmospheric Administration (NOAA) Chesapeake Bay Program, MCPS, the DCC, the ANS, and the NPS, as seen in Figure 2. The NOAA Chesapeake Bay Program is interested in an effective qualitative model to help students have a meaningful watershed educational experience. The MCPS Downcounty Consortium consists of five high schools (Kennedy, Northwood, Einstein, Blair, and Wheaton High Schools). The tenth-grade students in these schools will benefit from hands-on learning and field modules. The teachers and administrators from the schools have an interest in the success of the project. Diane Lill is the Director of Education at the ANS and the main author of the NPF proposal. Montgomery County Public Schools are responsible for evaluating the effectiveness of the distance learning program and their teacher training. The ANS and NPS are two significant stakeholders as the project directly aligns with their missions. They will provide on-site support for MCPS teachers during field investigations (National Park Service, 2017). All stakeholders have an interest in the successful implementation of the proposal.

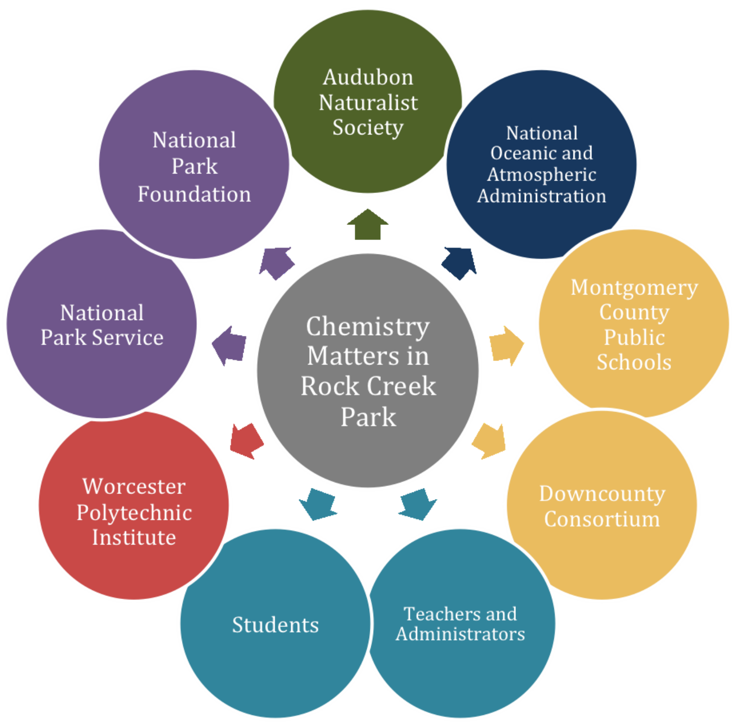


Figure 2: Stakeholders

The ANS was founded in 1897 with the goal of inspiring citizens to "appreciate, understand and protect their natural environment through outdoor experiences, education and advocacy" (Audubon Naturalist Society, n.d.). The ANS exclusively supports the Washington, D.C. metro area and is not affiliated with the National Audubon Society. Through collaboration with civic and environmental groups, the ANS reaches more than 9000 children per year through various programs. The ANS's education programs meet NGSS standards, providing "hands-on activities in the classroom and at the 30-acre Wooded Sanctuary" (Audubon Naturalist Society, n.d.). MCPS has developed and used programs with the ANS since 2005, recently launching the *Testing the Waters* program, which "provides gifted low-income high school students in the Downcounty Consortium of MCPS with meaningful, hands-on experiences in scientific water quality monitoring" (National Park Service, 2017). This program will be a model for the Chemistry Matters project.

1.3.6 Timeline

The full timeline of the NPF Proposal is in Appendix A. The first draft of the curriculum was completed in July of 2017. By 2020, the goals are to draft the final version of the curriculum and to continue teacher training. According to the timeline, the development of the distance learning program is scheduled to begin in January of 2018 (National Park Service, 2017).

1.4 Meaningful Watershed Education

The NPS and MCPS are responsible for delivering a Meaningful Watershed Educational Experience for MCPS high school students. The curriculum will inform students about waterways through hands-on learning and environmental literacy (National Park Service, 2017). Students will learn about watersheds, land where streams and runoff filter into a common body of water. Watersheds provide life to plants and wildlife as well as drinking water, flood relief, and recreation. Everyday human actions affect the quality of watersheds, including fertilizer usage, waste production and disposal, land development, and fuel usage (Montgomery Department of Environmental Protection, 2017).

The goal of the MCPS, NPS, and ANS Chemistry Matters program is to implement a MWEE. The program's core criteria is embedded in four key elements: issuing definition, outdoor field activities and experiments, data synthesis and conclusions, and action projects. The MWEE is a part of a greater initiative developed by the Chesapeake Bay Foundation to restore and protect the Chesapeake Bay Watershed Region.

The issuing definitions element of the MWEE curriculum guides students to focus on the driving question of the project and to address the problem at hand. MCPS students will explore the benefits of their watershed and how their actions affect the watershed. Students will conduct background research and gather data to understand the personal and public values associated with their local watershed.

Once MCPS students conduct their background research, they will perform assessments in the field on local waterways. The students will be guided by field experts and educators while practicing safe procedures. Students will test the quality of their water with chemistry kits and identify sources of pollution.

Students will synthesize the data they have collected from background research and outdoor field activities and will derive conclusions based on their findings. The MWEE providers hope that the student's findings and the program itself will instill lifelong environmental literacy and initiate civic action projects to help protect local bodies of water (Chesapeake Bay Foundation, 2017).

1.4.1 Importance of Watersheds

Watersheds encompass the majority of geographical land masses. The most common is an unplanned watershed, an area where development has occurred but the quality, integrity, and the repercussions of the development were not considered. Unplanned watersheds are common in older towns and cities where land was developed before environmental awareness and an emphasis on local watershed quality. In these cases, governments develop curriculum for responsible watershed management and policy, advocating for acceptable waste disposal, runoff limitations, and floodplain and basin development restrictions (What is a watershed. 2017).

There are different ways for conservancies to determine water quality. One method is to determine the quantity of benthic macroinvertebrates, which live at the bottom of the river and remain virtually stationary in heavy currents. Macroinvertebrates play a crucial role in the health of the river, naturally cleaning the water by feeding on algae and bacteria and leaving behind organic compounds and nutrients when they die. In polluted water, the population of pollutant tolerant macroinvertebrates such as worms and snails tends to remain the same or increase in size, whereas the pollutant susceptible macroinvertebrates populations tend to dwindle. ROCR consistently uses this technique to indicate the quality of their stream (Biological Monitoring, 2017).

Conservancies also determine water quality by testing chemical properties of water. These include dissolved oxygen, temperature, pH and nitrate levels. Dissolved oxygen is essential for fish and other aquatic species of fish and plants to breathe. The temperature of the water can affect the ability to hold dissolved oxygen, cold water holds oxygen better than warm water. The pH of water determines how acidic or basic it is, on a scale from 0 to 14. A pH of 7 is considered neutral, less than 7 is acidic and greater than 7 is basic. Pollution in the water can alter the pH, which is detrimental to plants and animals (Unites States Geological Survey,). Nitrates can assist in the growth of plants and animals, however, excessive nitrates are harmful. Nitrates found in the water can indicate the presence of pesticides in the water, disease-causing organisms, and organic and inorganic compounds that can cause health issues. Excess nitrates can cause eutrophication, which depletes oxygen in the water. Excess nitrates in humans can lower the oxygen carrying capacity of blood, which can be fatal, especially in infants (Benton Franklin Health District).

1.4.2 Watershed Education Modules

Watershed education programs are developed by local governments and conservation organizations to inform residents about their impacts on local waterways. Ample watershed education modules exist with similar structures and objectives. The ANS has developed an educational program called *Testing the Waters* geared towards low income students in Montgomery County that teaches students about conservation and STEM careers. This module has students assess biological, physical, and chemical properties of water, identifying benthic macroinvertebrates as biological indicators. Students are expected to use modern technology such as smartphone applications and laptops to reinforce their learning and make sharing data easier. The ANS has developed the Creek Critter App, which allows users to identify benthic macroinvertebrates and generate a stream health report based on the user’s location and findings. Students are encouraged to visit other streams, preferably in a different environment, comparing stream quality and assessing the reason for discrepancies (Naturalist Quarterly, 2017).

The New Hampshire Department of Fisheries and Wildlife has developed a watershed education module for state residents. This module is comprised of three phases and adheres to NGSS. In the first phase, students monitor water quality by identifying macroinvertebrates in the water. Phase two consists of watershed mapping and land use, using ArcGIS technology to share data and identify sources of pollution. In the final phase, students conduct a habitat assessment of the watershed, determining how species adapt to human impacts and pollution. At the end of the watershed module, the New Hampshire Department of Fisheries and Wildlife hopes to inspire students towards civic responsibility (NH Watershed Education Program).

1.4.3 Rock Creek Watershed

The Rock Creek watershed, as seen in Figure 3, consists of 75 square miles located within Montgomery county and Prince George county in Maryland. The creek flows southward out of Laytonsville, MD for 33 miles and empties into the Potomac River and Chesapeake Bay. Hundreds of thousands of people in the greater D.C. area interact with this watershed. The watershed fell victim to cultivation and urbanization in the mid-1860s before environmental damages were considered. Since it is located in a densely populated urban area, the watershed is often subjected to sewage overflow, industrial waste, and deforestation (The Watershed, 2003).

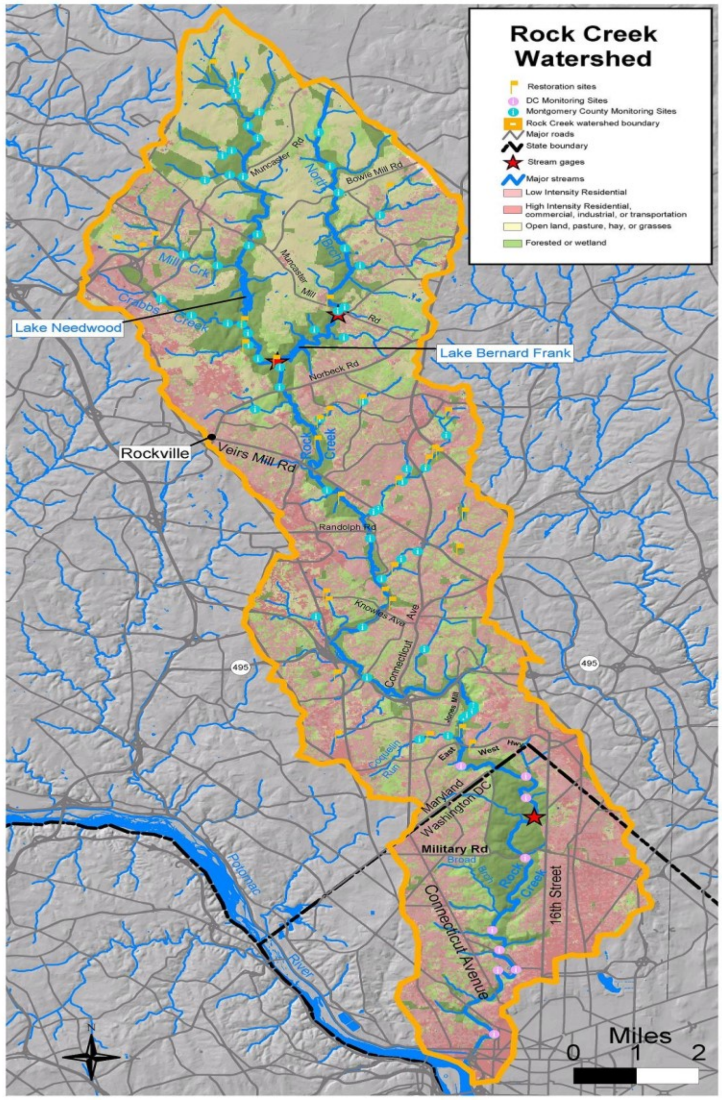
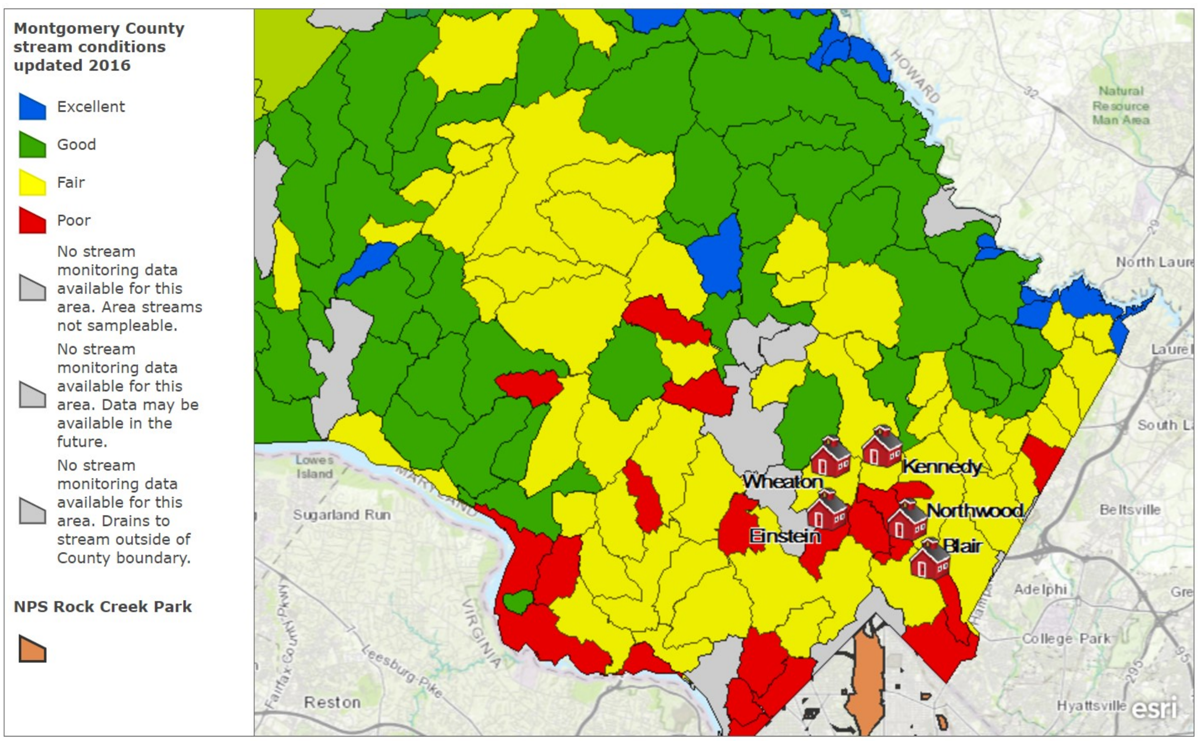


Figure 3: Rock Creek Watershed

ROCR, partnered with the Alice Ferguson Foundation, has developed curriculum and field modules to assess the quality of the watershed and promote learning in ROCR and local waterways. The modules encompass Water Quality Indexes, aquatic species assessments and inventories, sediment and street runoff, invasive species, insect life, and waste assessments. The modules are "designed to promote student academic achievement, personal connections with the natural world, lifelong civic engagement, and environmental stewardship through hands-on curriculum-based outdoor studies in national parks and public lands" (Bridging the watershed, 2015).

The watersheds surrounding the D.C. Metro area are deemed one of the top three areas of concern in the Chesapeake Bay Region. Rapid urbanization has severely degraded the quality of life surrounding the water. Polychlorinated biphenyls and chlordane insecticides have been prevalent in the sediments of the river bed, which overtime, caused harmful side effects for aquatic species and frequent swimmers.

The Downcounty Consortium is located within the Greater D.C. Metro Area. As seen in Figure 4, all the schools in the consortium are in areas of the watershed where water quality is rated either fair or poor due to their proximity to an industrialized urban area. The schools within the consortium have a predominantly minority population with Hispanic and African American students comprising 67% of the district's population (Table 1).



City of Rockville, Montgomery County, MD, VITA, Esri, HERE, Garmin, Intermap, USGS, NGA, EPA, USDA, NPS

Figure 4: Stream Conditions in Downcounty Consortium

School	#Grade 10 Students	#African American	#Hispanic	#Asian	# More than 2 Races	#White	#FARMS (free/reduced price meals)
Kennedy	246	83	128	20	4	11	128
Northwood	274	76	120	23	10	45	128
Einstein	167	34	57	20	4	52	57
Blair	444	121	121	49	32	120	152
Wheaton	394	110	166	75	9	34	183
TOTAL	**1524**	**422**	**592**	**188**	**59**	**262**	**647**
%		**28%**	**39%**	**12%**	**4%**	**17%**	**32%**

Table 1: Montgomery County Demographics

(source: National Park Service, 2017)

1.5 Engaging Students in Citizen Science

An outcome of the Chemistry Matters in Rock Creek project is to interest students in citizen science through hands-on learning. Students participate in an online component such as educational games, videos, websites and data sharing methods.

1.5.1 Education Games for STEM Education

Educational games have recently been used to engage students and compliment learning outside the classroom. Dondlinger (2007) recommends educational games which require "strategizing, hypothesis testing or problem-solving" and "wandering and alternatives" rather than edutainment, which "often fails in transmitting non-trivial knowledge". Vogel et al. (2006) echoed this opinion and found learners preferred programs where they controlled their navigation, adding that the "level of picture realism … did not alter the results". Dondlinger also found that educational games typically have rewards and goals to motivate the learner to continue playing. When implementing educational games, Bouchard, Guillemette, Mueller, and O'Keefe (2006) found that many educators were concerned that the programs did not have educational value and would not meet government curriculum requirements. Overall, educational games have been found to be a useful medium for engaging students.

Studies into the use of educational games for STEM education have shown mixed results. Mayo (2009) found that educational games have "diminished the learning gap between D and B students, to the point where all students are performing at the B level" and they can "yield a seven to 40% positive learning increase over a lecture". However, Young et al. (2012) found that there is "little support for academic value of video games in science and math" and found educational games had inconclusive effects on academic achievement. The group also found that in an ecology based massive multiplayer online game, students showed "significantly lower test scores". This is concerning, but a well-designed game can account for this by not having virtual worlds entirely substitute for direct experiences. In summary, at this time, educational games in science and math have not been found to show substantial improvement in academic performance.

1.5.2 Videos for Education

Videos can be used to supplement classroom teachings. A study was done to determine whether videos are effective when encouraging students to pursue STEM careers. The study analyzed videos detailing STEM professionals at their jobs in their work environments. The results of the study suggest that the viewing of videos is related to an increased interest in STEM careers and students will benefit from these types of videos. Changing students' interests requires multiple platforms to be introduced gradually. A video can be one platform used in sequence with other methods to introduce students to STEM careers (Wyss, Heulskamp, & Siebert, 2012).

Chapter 2: Methodology

Through partnering with the National Park Service at Rock Creek Park and the Audubon Naturalist Society, Montgomery County Maryland Public Schools aims to establish a "meaningful watershed education experience" and to pique students' interest in science, technology, engineering and math. The project resulted in the development of a three-day curriculum that includes an introduction to the topic, videos demonstrating water chemistry tests, a workbook with procedures, and recommendations for data analysis and reflection.

Our team's objectives and steps are outlined in Table 2.

Objective 1: Drew Ideas from Existing Programs
1. Assembled National Park Service Guidelines
2. Reviewed Rock Creek Park educational programs in relation to NPS guideline
    i. Compared programs to guidelines
    ii. Observed existing field module
    iii. Discussed with liaison
    iv. Consulted with other education specialists
3. Reviewed existing watershed education programs
4. Shared insights and promising possibilities with colleagues

Objective 2: Determined Educational Elements 1. Researched education elements: Data sharing website, Video, Educational video games, Phone application 2. Prioritized education possibilities 3. Consulted with sponsor and stakeholders

Objective 3: Implements Education Elements
1. Developed educational elements
    i. Interactive Presentation
    ii. Video
    iii. Workbook
2. Tested the educational elements with stakeholders, students and teachers
    i. Test elements with sponsor
    ii. Test elements with stakeholder
    iii. Test elements with students
3. Incorporated feedback and improved the design through multiple revisions

Table 2: Objectives Outline

2.1 Drew Ideas from Existing Programs

Ideas from existing citizen science watershed education programs were compiled, specifically from NPS, HOL, *Bridging the Watershed, Testing the Waters,* etc. Several chemistry field modules were observed at a stream near John F. Kennedy High School in Montgomery County, Maryland. The observations during this program served as the basis for in-class activities. We conducted a literature review of the NPS guiding principles, best practices, and goals for improvement. Existing programs were compared to the NPS guidelines. Findings were shared with stakeholders and colleagues to gather suggestions and recommendations.

Step 1: Assembled National Park Service Guidelines

Through a literature review of NPS educational program guidelines, we summarized guiding principles, best practices, and goals for program improvement (Table 3). This task gave insight into the status of current NPS programs and their structures.

Guiding Principles (U.S. National Park Service, 2003)	1. Place-based 2. Learner-centered 3. widely accessible 4. based on sound scholarship content, methods and audience analysis 5. Help people understand and participate in U.S. civil democratic society 6. Incorporate ongoing evaluation for improvement and effectiveness 7. Collaborate and create partnerships with other agencies and institutions
Best Practices (Bowling, 2013)	1. Provide training, networking, and coaching resources 2. Leverage education professionals outside agency 3. Leverage expertise of more successful park education programs 4. Leverage common concepts between education and interpretation
Goals for Improvement (U.S. National Park Service, 2006)	1. Engage people to make enduring connections to America's special places a. Create programs in collaboration with local communities 2. Use new technologies 3. Embrace interpretation and education partners 4. Develop and implement professional standards 5. Create a culture of evaluation a. "We have very little scientifically valid information about the direct outcomes and impact of interpretation and education programs."

Table 3: National Park Service Guidelines

Step 2: Reviewed Rock Creek Park educational programs in relation to NPS guidelines

Step i: Compared programs to guidelines

After assembling National Park Service guidelines, the opportunities and insights offered were evaluated. Rock Creek Park programs were set within this framework.

Step ii: Observed existing field module

A trial field module (Figure 5) at John F. Kennedy High School provided valuable insights into the structure of the program. Various inconsistencies and issues became apparent and were important when prioritizing educational elements.

Figure 5: Students at trial field module

Step iii: Discussed with liaison

The project liaison, Maggie Zadorozny, is an education specialist at Rock Creek Park and possesses valuable insight into the structure of existing educational programs. She guided the project and offered feedback throughout.

Step iv: Consulted with other education specialists

Other education specialists at the NPS, ANS and MCPS provided insight and recommendations for the program.

Step 3: Reviewed existing watershed education programs

Several watershed education programs exist within the Rock Creek and the Chesapeake Bay watersheds, such as the *Bridging the Watershed* and *Testing the Waters* programs. After reviewing these programs, the use of modern technology and data sharing is present. These programs inspire students and demonstrate community impact on watershed quality.

Step 4: Shared insights and promising possibilities with colleagues

After compiling information and recommendations, we presented these findings to our colleagues at the NPS, MCPS, and ANS. We incorporated their feedback into the final design, as these colleagues will lead and maintain the program. This resulted in the creation of an electronic library of curriculum materials.

2.2 Determined Educational Elements

We researched educational video games, websites, phone applications and videos as possible educational elements. Using principles from the previous section, we developed a method for integrating the chosen elements into the education component. The decision was made to create an interactive presentation with embedded videos to introduce the students to watershed quality, how-to videos for each of the water quality tests, and a workbook.

Step 1: Researched educational elements

We reviewed existing educational elements and identified the most relevant elements to the project.

Option i: Data sharing website

There are existing websites that are useful for sharing data. Relevant findings and recommendations are found in the following chapter.

Option ii: Video

Many education programs use videos to engage and excite students with the curriculum. We reviewed successful science education videos and determined that although many of them had relevant content, none of them covered all of the material required. Therefore, we gathered all the relevant and useful elements from the videos and incorporated it into our educational program.

Option iii: Educational video games

Educational video games can be an effective method of engaging students. After considering the time requirements for developing a game, this option was not pursued.

Option iv: Phone application

Phone applications such as ANS Creek Critters and CitSci.org were reviewed. Relevant features and use cases were analyzed to allow for potential future implementation.

Step 2: Prioritized educational possibilities

The most feasible education elements were examined. The stakeholders were consulted to determine which educational possibilities best fit the project.

Step 3: Consulted with sponsor and stakeholders

Throughout the project, we consulted with the sponsor and stakeholders on education elements that best fit with the curriculum. During weekly meetings with stakeholders, we discussed the progress of project and the work we had done to that point.

2.3 Implemented Educational Elements

The curriculum materials were implemented by following the plan established in Section 2.2. Changes were made based on sponsor and stakeholder feedback.

Step 1: Developed educational elements

Option i: Interactive presentation

An interactive presentation is the "hook" for the field module. It aims to grasp the student's interest in the subject matter and guides them through the program.

Option ii: Video

Videos were the highest priority of the stakeholders. Due to student confusion during the field modules, videos demonstrating the written procedure were produced. The team filmed and edited three videos detailing the field tests and created a video explaining where the county drinking water originates.

Option iii: Workbook

The "Citizens on Patrol: A Guide to Protecting Your Watershed" workbook (Appendix B) consists of pre-lab questions, explanations of each test, the revised procedures and post-lab questions.

Step 2: Tested the educational elements with stakeholders, students and teachers

Step i: Test elements with sponsor

The program was first tested and reviewed by our liaison and colleagues at the NPS. Their feedback was instrumental in the early stages of development.

Step ii: Test elements with stakeholders

After testing the program with the NPS, colleagues at the ANS and MCPS experienced the program as if they were a student. They have worked with the

NPS in the past and are heavily involved in the outcome of the project and provided valuable feedback.

Step iii: Test elements with students

After the module was developed, a group of students from *Bridging the Watershed* tested the procedure. The students provided feedback and suggestions. Next school year, MCPS teachers will pilot the program with their classes. Along with colleagues at the ANS and NPS, they will address any issues that arise when the program is implemented with a larger audience.

Step 3: Incorporated feedback and improved the design through multiple revisions

Comments and feedback were sought throughout every step of the project in order to allow for continuous improvements.

Chapter 3. Project Outcomes and Recommendations

The MCPS high school chemistry curriculum includes a term-long project researching alternative-fuel vehicles. This project is ten weeks long with several subsections. The purpose is to connect energy and water by studying the effects of fossil-fuel emissions on the quality of local creeks and streams. MCPS has allotted three days for the water quality curriculum, with each class being 45 minutes with 30 minutes of actual content. This chapter communicates the project outcomes and recommendations for each day of the three-day module (Figure 6*)*. Day 1 introduces students to the topic, shows them its significance, engages the students and prepares them for the field module. On Day 2, students go to a creek or stream that is near their school and test the water using LaMotte test kits. On Day 3, the students analyze and share their data.

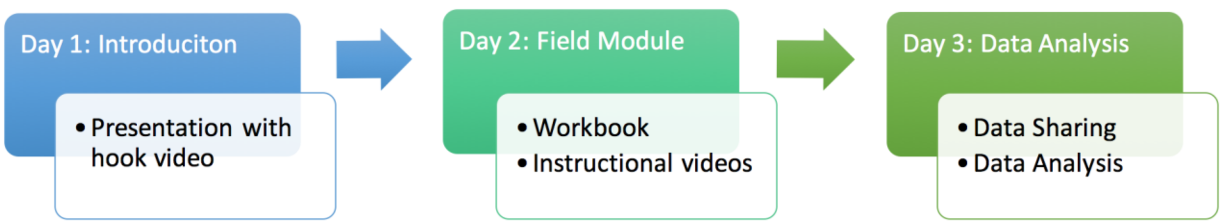


Figure 6: Three-Day Curriculum Outline

The education program fulfills the objectives of the Chemistry Matters project (Table 4).

MCPS will grow in its understanding and appreciation of the value of Parks as resources for place-based learning
MCPS chemistry teachers will gain confidence teaching hands-on NGSS environmental literacy standards
MCPS DCC High School students will experience hands-on learning in Rock Creek Park to connect classroom learning with real world applications and problem solving
MCPS DCC High School students will develop an understanding of NPS resource management and conservation career opportunities as a result of the partnership with Rock Creek Park
A long-term partnership developed among MCPS, ANS, and NPS will support field-based learning in parks for underserved students in the county

Table 4: Chemistry Matters Overall Project Outcomes

Source: (National Park Service, 2017)

3.1 Day 1: Introduction to Water Chemistry Testing

Prior to this project, MCPS had no successful introduction that engaged students with water chemistry. The stakeholders wanted curriculum that taught students the importance of water quality and wanted this be done through an interactive medium that tied water to energy. Students participated in a pilot field module in October 2017. The students were unfamiliar with the tests and what the significance of the data was. Therefore, the materials for Day 1 focus on addressing where the students get their drinking water and the significance of water chemistry analysis. Day 1 consists of an interactive presentation completed on Google Slides, a platform like PowerPoint that is used by MCPS. The presentation introduces students to water chemistry and includes time for discussion and videos.

3.1.1 Introductory Hook Video

The two-minute hook video is the opener to the presentation. It shows students the importance of their local stream quality and the purification process of drinking water. Many students are unaware that their drinking water indirectly comes from local streams. After reviewing many videos on water quality and drinking water in the DC metro area, it was found that none of them completely covered the curriculum needs. However, the videos that were produced by DC Water, the WSSC, and Bill Nye had elements that partially covered what the topic. A video was produced that blended the effective elements of these videos, and satisfied the curriculum needs.

3.1.2 Instructional Videos

Students struggled while conducting the chemistry water quality tests during the pilot field modules. The project’s stakeholders felt that exposing students to the procedures beforehand would improve student success in the field. Instructional videos were produced that walk students through the dissolved oxygen, temperature, pH, and nitrate tests. The stakeholders recommended that these videos be our highest priority.

3.1.3 What to Expect Video

During the pilot program, students arrived at the site unprepared. To address this issue, the presentation gives an overview of what to expect and how to dress when going outdoors for water chemistry analysis.

3.2 Day 2: Field Module: Water Chemistry Testing at the Stream

During the project, four classes were observed at a pilot field module at a stream near John F. Kennedy High School. Students tested the waters at a local stream by analyzing temperature, pH, alkalinity, nitrates, phosphates, transparency and dissolved oxygen. It quickly became clear that improvements were needed to allow for a better learning experience. Most of the issues were related to time constraints and unclear instructions. To solve these problems, the number of tests were reduced to just dissolved oxygen, pH and nitrates. Deliverables for Day 2 include a workbook for students and revised procedures.

3.2.1 Revised Water-Testing Procedures

The original instructions were provided by the water quality lab kit manufacturer. They were designed for more experienced users and confused many students who had never done chemical analysis before. Many students skipped steps or completed the procedure out of order, which caused delays, inaccurate data, and a loss of student interest. Students had difficulty following the directions for the dissolved oxygen test. The instructions were rewritten to improve clarity and make them easier to follow. First, the instructions were tested by the WPI team using local stream water. Then, a park ranger who was unfamiliar with water quality testing conducted the experiments using the revised procedures and found similar results. Finally, the revised procedures were tested with a group of students. Overall, it was found that the revised procedures were easier for the students to follow, and the students were successful in collecting accurate data.

3.2.2 Workbook: Citizens on Patrol: A Guide to Protecting Your Watershed

The team created a workbook entitled "Citizens on Patrol: A Guide to Protecting Your Watershed" that lays out information for the students and guides students through the three-day process, with an emphasis on Day 2. Citizens on Patrol includes pre-lab questions, the rewritten water testing procedures, space to write observations, where to find the instructional videos, analysis questions pertaining to each experiment, and reflection questions. It is anticipated that Citizens on Patrol will be used throughout the three-day experience. Students will reference it on Day 1, follow the procedures on Day 2, and use their findings in Citizens on Patrol on Day 3.

3.3 Day 3: Recommendations for Analysis and Data Sharing

For Day 3, students will analyze their findings and compare results found during the field module. Students will compare data with other classmates, classes, and schools. They will find and explain discrepancies in their data as well as identify the pollutants that could be in their stream. The analysis can be a homework assignment, a reflection in the workbook, or a class discussion. Additionally, the recommendations include the adoption of a data sharing platform, such as CitSci.org which will allow students to complete these tasks.

Currently, there is no method for students to share and analyze findings between different classrooms and schools. Project stakeholders identified this issue, but asked for a prioritization of the content for Day 1 and Day 2. Thus, Day 3 consists mainly of recommendations and not deliverables.

3.3. Create a water quality index for analysis of stream quality

It is recommended that a water quality index that combines the three tests be created. This will allow for one final grade of stream quality that considers dissolved oxygen, pH, and nitrates. It will help address a scenario where tests disagree with each other.

3.3.2 Establish a way for students to share data

Data sharing would allow students to see trends within their class, school and county. Several data sharing platform possibilities were reviewed. One option includes creating a new data sharing platform using Google Drive. This would allow for greater flexibility on the stakeholders' end, but would require more effort and maintenance than third-party options. Another option is to use an existing platform. The following programs have been reviewed: CitSci.org, Hands on the Lands, Field Scope, iNaturalist and ANS Creek Critters. However, CitSci.org has been found to be the best platform.

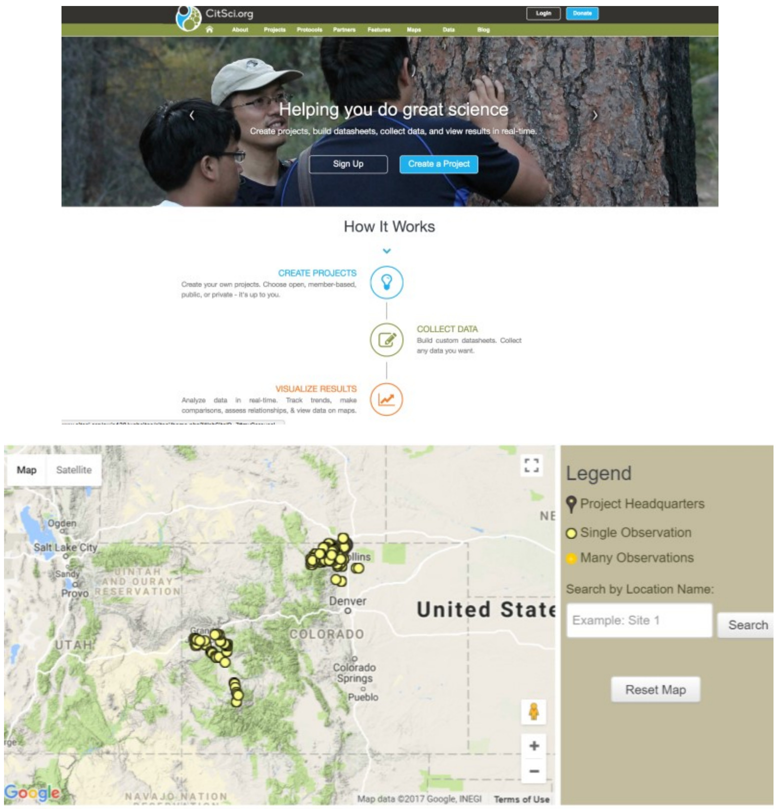


Figure 7: CitSci.org

CitSci.org (Figure 7) is a website for data management of citizen science projects. Their vision is to "provide comprehensive support for citizen science programs globally" by "supporting the full spectrum of citizen science needs", "elevating the rigor of citizen science data", and "improving data standardization, interoperability, integration, accessibility, and dissemination" (CitSci.org, n.d.). This website allows organizers to specify the tests and generates a data sheet for data entry. The students choose their school from a drop-down box, allowing comparison with other schools in the area. This allows for a map (Figure 7) of the county's results to be generated. Graphs can also be created for a school or a class. CitSci.org claims that all features can be accessed on desktop, tablet, and smartphone, but this claim has not been verified. Their mobile app also contains an offline mode. The website allows students to analyze data through summary statistics and to compare variables, allowing for an outlier analysis. The data visualization features give students the chance to gain a better understanding of their results. CitSci.org seems to be the best option available for data sharing.

3.3.3 Have students research storm water facilities and watershed health

After analyzing and sharing data, it is recommended that students research Montgomery County storm water management and watershed health. Students can brainstorm actions that could be taken to improve their water quality. Montgomery County is already doing several things to address storm water runoff. The Montgomery County Department of Environmental Protection has several resources on their website that could provide students with ideas to combat storm water runoff. A description of current efforts is found on their website in addition to a Geographical Information System of storm water facilities (Montgomery County Department of Environmental Protection, n.d.). This could be a useful tool to allow students to see what the County is doing near their school or in their neighborhood.

Montgomery County Department of Environmental Protection maintains information about local watersheds and stream flow on their website. Students can look at the data for their school or neighborhood under the “Find Your Watershed” section.

This recommendation would help teach students analytical and investigative skills. Additionally, it shows the students that the county is taking an initiative to remedy a problem.

3.4 Additional Recommendations

In addition to the curriculum elements discussed above, the following recommendations detail additional ideas to expand the project.

3.4.1 Further test the educational elements with students

The educational elements and deliverables of this project have yet to be fully tested with MCPS students. It is recommended that stakeholders evaluate the materials with students and make changes based on student feedback. This allows for the advancement of materials to better suit student needs.

3.4.2 Have opportunities for Student Service Learning

The students will only conduct three water chemistry tests and will therefore have a limited amount of data for analyzing stream quality. The chemistry tests are a snapshot of stream quality at a certain time. To see the long-term water quality, it is best to do a macroinvertebrate survey. Students are required to participate in Student Service Learning, which could provide an opportunity for a few students to conduct the macroinvertebrate survey and share their findings with others.

3.4.3 Establish independent learning environment for module

Students at MCPS already use Canvas, an online learning management system. The presentation, workbook and videos could be uploaded to Canvas, allowing students easy access to these resources. Additionally, the presentation could be ported to a Canvas module with quizzes. This could allow for students to have a self-guided lesson rather than a teacher-led presentation. Additionally, it allows for more individualized evaluation of student progress. This would allow teachers to adjust lessons based on class responses.

3.4.4 Share educational elements with other national parks

This initiative is being done in other national parks throughout the United States. Therefore, it would be beneficial to share the deliverables with those parks. Not only would this increase the impact of the project, but it could allow for feedback from others that are invested in the success of the program.

3.4.5 Expand module to be interdisciplinary

The Citizen Science 2.0 program can be expanded outside of chemistry to other subjects such as social science and biology. Students could look at the factors affecting watershed health from different points of view and visit their outdoor classrooms more than once.

3.4.6 Have a future WPI IQP team continue the project

There are plenty of opportunities to expand upon this project. Day 3 needs more work to further develop the data sharing platform. Additionally, there will likely be challenges when expanding this program to all MCPS high schools. The stakeholders had some desire to educate students about STEM careers, especially within the National Park Service. This had originally been a goal of the project, but the stakeholders felt the other aspects of the project outweighed that goal at this time. However, a module about STEM careers could be empowering for the students in Montgomery County. These recommendations could be addressed in future IQPs.

References

Alexander, L. (2017a). Naturalist quarterly. ().Audubon Naturalist Society

Audubon Naturalist Society. Audubon naturalist society. Retrieved from https://anshome.org/mission/

Audubon Naturalist Society. (n.d.). Creek Critters app. Retrieved from https://anshome.org/creek-critters/

Benton Franklin Health District.What are nitrates? Retrieved from http://www.bfhd.wa.gov/info/nitrate-nitrite.php

Biological monitoring (2017).

Bonney, R., Cooper, C. B., Dickinson, J., Kelling, S., Phillips, T., Rosenberg, K. V., & Shirk, J. (2009). Citizen science: A developing tool for expanding science knowledge and scientific literacy. Bioscience, 59(11), 977-984.

Bouchard, M. A., Guillemette, M., Mueller, E. M. & O'Keefe, S. C. (2006). Interactive learning modules for the royal armouries education centre. Retrieved from Worcester Polytechnic Institute Electronic Projects Collection: https://web.wpi.edu/Pubs/E-project/Available/E-project-042406-100759/

Bowling, K. A. (2013). The understanding and implementation of key best practices in national park service education programs. Journal of Interpretation Research, 18(1)

Bridging the watershed. (2015).

Bushong, W. (1990). Historic resource study: Rock creek park, district of columbia US Dept. of the Interior, National Park Service.

Cameron, J. (1922). The national park service: Its history, activities, and organization D. Appleton.

CitSci.org. (n.d.). Http://www.citsci.org. Retrieved from http://www.citsci.org/cwis438/websites/citsci/home.php?WebSiteID=7

Dondlinger, M. J. (2007). Educational video game design: A review of the literature. Journal of Applied Educational Technology, 4(1), 21-31.

INaturalist.org. (n.d.). Retrieved from https://www.inaturalist.org/

Mackintosh, B. (1985). Rock creek park: An administrative history.

Mayo, M. J. (2009). Video games: A route to large-scale STEM education? Science, 323(5910), 79-82.

Montgomery county department of environmental protection: What is a watershed. (2017).

A national network of field classrooms - hands on the land. Retrieved from https://handsontheland.org/

National Park Foundation.We are parks, 2016 annual report. 2016,

National park service (2017) chemistry matters in rock creek: Citizen science in the rock creek watershed through chemistry. (proposal for development of a high school chemistry watershed module by montgomery county public schools in partnership with rock creek park and audubon naturalist society). washington, DC: National park foundation.

National Research Council. (2013). Next generation science standards: For states, by states

Powering Citizen Science. (n.d.). Retrieved from http://www.fieldscope.org/

Rock creek conservancy: The watershed. (2003). ().Rock Creek Conservancy.

Sprague, S., Green, A., Baker, T., Schabow, K., O'Neal, E., & Pizzala, A. (2017). An educator's guide to the meaningful watershed educational experience. ().Chesapeake Bay Foundation.

Tumosa, J.NH watershed education program NH Department of Fisheries and Wildlife.

United States National Park Service. (2006). Interpretation and education renaissance action plan National Park Service, U.S. Department of the Interior.

United States., National Park Service. (2003). Renewing our education mission : Report to the national leadership council. Retrieved from https://purl.fdlp.gov/GPO/gpo82599

United States., National Park Service. (2017). National park service overview. Retrieved from https://purl.fdlp.gov/GPO/gpo79838

United States Geological Survey.Water properties: Dissolved oxygen. Retrieved from https://water.usgs.gov/edu/dissolvedoxygen.html

US National Park Service.About us: National park service. Retrieved from https://www.nps.gov/aboutus/index.htm

Vogel, J. J., Vogel, D. S., Cannon-Bowers, J., Bowers, C. A., Muse, K., & Wright, M. (2006). Computer gaming and interactive simulations for learning: A meta-analysis. Journal of Educational Computing Research, 34(3), 229-243.

Wyss, V. L., Heulskamp, D., & Siebert, C. J. (2012). Increasing middle school student interest in

STEM careers with videos of scientists. International Journal of Environmental and Science Education, 7(4), 501-522.

Young, M. F., Slota, S., Cutter, A. B., Jalette, G., Mullin, G., Lai, B., . . . Yukhymenko, M. (2012). Our princess is in another castle: A review of trends in serious gaming for education. Review of Educational Research, 82(1), 61-89.

Zadorozny, M.In McCarthy T., Perkoski J., Galgano M. and O'Brien K.(Eds.), Interview with maggie zadorozny - NPS

Appendix A: NPF Proposal Timeline

2017	
July	First draft of new NGSS-aligned Chemistry curriculum is completed by MCPS
August	First teacher trainings are being held for Kennedy High School based on the first draft of curriculum; project partners loan materials and attend the training to get an idea of how they can best support a field investigation module as part of the curriculum
September-December	Kennedy High school teachers pilot the curriculum developed by MCPS; STARTUP PHASE BEGINS: ANS and NPS formally join as partners; attend lessons at Kennedy High School; begin to revise and expand upon curriculum using extensive water quality monitoring expertise; identify roles for technology such as the use of the ANS Creek Critters app as citizen science component; collaborate to identify field trip opportunities and school presentations that will tie in park resources and data; include other interested contributors as decided by the partnership; and identify opportunities for seeking matching funds to develop program in years two and three
2018	
January-March	DEVELOPMENT PHASE BEGINS: ANS, Rock Creek Park, and MCPS collaborate on development of the field investigation module and the partnership opportunity identified with Rock Creek Park; all partners agree on best field study sites for each school and being development of the watershed module to be piloted in the fall; and partners begin exploring development of a distance learning component using Rock Creek Park and the creation of a video highlighting NPS careers
April-May	Test implementation of the new module with select students from Kennedy and Northwood High Schools; students participate in field studies at Rock Creek Park to collect data and test revised module lessons before they are rolled out in the fall
June-August	Final revisions of the module are made by MCPS with input from ANS and NPS; Teacher training held in August for teachers from Kennedy, Northwood, and Einstein is led by all three partners (MCPS, ANS, and NPS)
September-December	IMPLEMENTATION PHASE BEGINS: Pilot of the experiential module, including field studies and partnership with Rock Creek Park, occurs with Kennedy, Northwood, and Einstein High Schools

2019	
January-March	Partners analyze feedback from pilot at Kennedy, Northwood, and Einstein; continue to make revisions to module
April-May	Test revised module lessons with students from Kennedy and Northwood High School; students participate in field investigations to Rock Creek Park to collect data
June-August	Preparation for teacher training in August for teachers from all five DCC high schools: Kennedy, Northwood, Einstein, Blair, and Wheaton
September-December	Full rollout of field experience module at all five Downcounty Consortium High Schools: Kennedy, Northwood, Einstein, Blair, and Wheaton
2020	
January-March	Partners analyze feedback from all five high schools and continue to refine module; final version of module is drafted
April-August	Continue implementation of partner roles in planning for continued trainings for teachers in the coming school year

Source: (National Park Service, 2017)

Appendix B: Workbook for Field Modules

Citizen Science 2.0: Chemistry Matters

Citizens on Patrol:
A Guide to Protecting Your Watershed

Name:___________________________________ Date:______________

Location of Analysis:____

Pre-Lab Questions:

1. What is a watershed?

2. Where does the stream you are testing lead?

3. Describe several factors that could affect water quality.

4. Do you think the stream is healthy? Why?

5. What do you think are the main pollutants of your stream?

Dissolved Oxygen

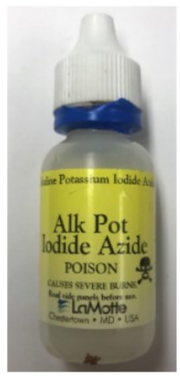
Aquatic organisms, such as fish, invertebrates, plants and aerobic bacteria need dissolved oxygen to live. Oxygen dissolves readily into water from the atmosphere until the water is saturated. Once dissolved in the water, the oxygen's rate of diffusion depends on the movement of the aerated water. Oxygen is also produced by organisms, such as aquatic plants, algae and phytoplankton, as a byproduct of photosynthesis.

Determining dissolved oxygen in ppm or equivalently mg/L

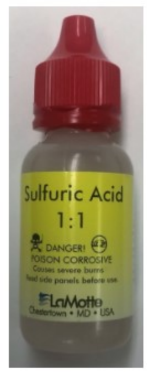
Water Sampling Bottle

Manganous Sulfate

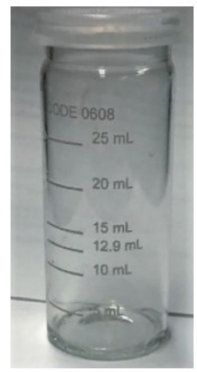
Alkaline Potassium Iodide Azide



Sulfuric Acid



Reaction Vessel



Part 1: **Prepare your sample**

1. Find <u>flowing</u> water and submerge the **Water Sampling Bottle** completely underwater. Fill the bottle completely (tap the sides of the bottle to get rid of air bubbles) and cap the bottle while it is still underwater.
2. Add *8 drops* of **Manganous Sulfate Solution ($MnSO_4$)** (pinkish liquid, white cap) to the **Water Sampling Bottle**.
3. Add *8 drops* of **Alkaline Potassium Iodide Azide** (Clear liquid, white cap) to the **Water Sampling Bottle**.
4. Cap and mix the solution, forming precipitates.

5. Set the bottle aside and wait for the precipitates to settle below the shoulder of the bottle.

Before:

After:

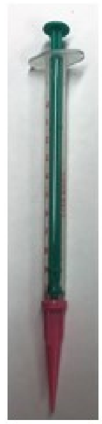
6. Add *8 Drops* of **Sulfuric Acid (H_2SO_4)** (red cap) to the **Water Sampling Bottle** and mix until the precipitates dissolve fully.

7. Fill the glass **Reaction Vessel** with *20 mL* of this liquid, ensuring the bottom of the meniscus is at 20 mL. Snap the plastic cap on top.

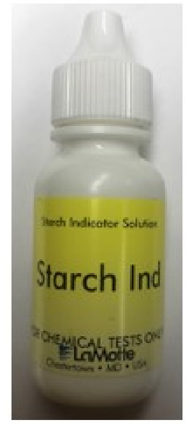
STOP

Sodium Thiosulfate

Titrator



Starch Indicator



***Part 2:* Titration**

1. Place the tip of the **Titrator** (small syringe) into the **Sodium Thiosulfate ($Na_2S_2O_3$)** (black lid). With the help of a partner, turn the bottle and titrator upside down. Pull the plunger down until the ring on the plunger reaches *0.0*. If there are any air bubbles, push the liquid back into the bottle and repeat the process.

2. Insert the tip of the titrator into the lid of the glass **Reaction Vessel**. Add *one drop* from the **Titrator** and swirl the solution. Keep adding <u>one drop at a time</u> until the solution changes from yellow-brown to pale yellow. DO NOT empty the titrator.

3. Take the **Starch indicator ($C_6H_{10}O_5$)** (white lid) and shake the bottle. Add *8 drops* of the Starch indicator to the glass **Reaction Vessel**.

4. Using the **Titrator**, add one drop of Sodium Thiosulfate to the **Reaction Vessel** and swirl. Repeat until the solution begins to become clear. Once the solution becomes completely clear, <u>STOP</u>. Using a white piece of paper as a backdrop will help you see how clear the solution is.

5. Read the **Titrator** and record the value in *ppm of dissolved oxygen.

ppm of Oxygen: _____________

*ppm = mg/L

***Part 3:* Determine percent saturation of dissolved oxygen**

1. Determine the temperature of the stream. Hold the thermometer roughly 4 inches below the surface of the water, but do not let it touch the bottom of the stream. Wait 2 minutes, and read the temperature (°C) while the thermometer is still in the water.

   Temperature:_______________ °C

2. Circle the dissolved oxygen quality of the stream:

Dissolved Oxygen					
Poor	Fair	Good	Excellent	Good	Fair
< 50%	**50 - 70%**	**70 - 80%**	**80 - 120%**	**120 - 140%**	**> 140%**

★ **What factors lower and raise dissolved oxygen levels in the stream?**

pH

pH is one of the most common variables looked at in water testing. It is a measure of the hydrogen ion (H+) concentration in the sample. pH ranges from 0-14, with 7.0 considered neutral. Solutions with a pH below 7.0 are considered acidic, and those with a pH above 7.0 are considered alkaline or basic.

1. Fill a **test tube** to the *10 mL* line with sample water
2. Add *10 drops* of **Wide Range pH Indicator**
3. Cap and mix the **test tube**
4. Insert **test tube** into the **viewer.** Hold the **viewer** so non-direct light enters through the back. Match sample color to a color standard.
5. Record the pH.

   pH:____________
6. Circle the pH quality of the stream:

pH						
Poor	Fair	Good	Excellent	Good	Fair	Poor
< 5.5	**5.5 - 6.5**	**6.5 - 7.0**	**7.0 - 7.5**	**7.5 - 8.5**	**8.5 - 9.0**	**> 9.0**

★ **Why are too high and too low pH levels detrimental to the health of the stream?**

Nitrate (NO_3)

Both plants and animals need nitrogen to build protein and nucleic acids. In nature, nitrogen is much more abundant than phosphorous and is most commonly found in the atmosphere in its elemental form (N_2). Nitrogen enters the water through natural processes, but humans contribute to high levels of nitrates. Runoff from the land can contain nitrates from: fertilizers, sewage from leaky cesspools or sewage pipes, manure from livestock, and car exhaust.

1. Insert slide bar into viewer
2. Fill a **test tube** to the *5 mL* line with sample water.
3. Add one **Nitrate #1 Tablet** (foil packet with red writing).
4. Cap and mix until tablet disintegrates.
5. Slide the test tube into the silver **protective sleeve**. Add one **Nitrate #2 Tablet** (foil packet with purple writing).

   Nitrate #2 CTA Tablets are sensitive to UV light. The Protective Sleeve will protect the reaction from UV light. If testing indoors, there is no need to use the Protective Sleeve in this procedure.

6. Cap and mix for <u>two minutes</u> to disintegrate the tablet.
7. <u>Wait 5 minutes</u>. Remove the tube from the **protective sleeve**.
8. Insert test tube into viewer.
9. Match sample color to a color standard.

   Record value: ______________

10. Multiply value by 4.4 to find Nitrate level

   Nitrate ppm: _______________

11. Circle the nitrate quality of the stream:

Nitrate			
Excellent	Good	Fair	Poor
< 1 ppm	**1 - 5 ppm**	**5 - 10 ppm**	**> 10 ppm**

★ **Why are high nitrate levels dangerous to the health of the stream?**

Post-Lab Questions:

1. What type of data would you expect in a healthy stream?

2. What do your water quality test results show?

3. Do all the parameters tested support the same conclusion? If not, what do you think could cause discrepancies?

4. If past water quality test results are available, how does the present results compare with the previous results? Have any actions taken by the community led to any negative or positive changes?

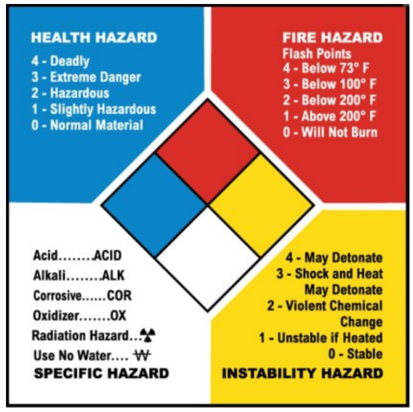
5. What different types of pollution can you identify in your local community?

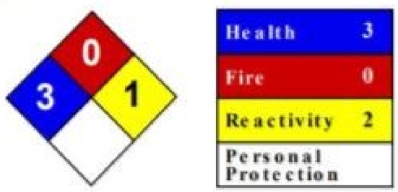
6. Do you think any water quality problems in your local community will improve in the next 5 years?

7. What are some things you can do to improve water quality?

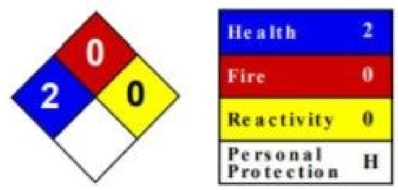
Chemical Safety

Wear appropriate Personal Protection Equipment (PPE) when handling chemicals!

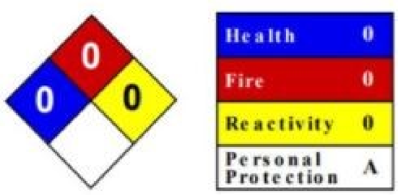




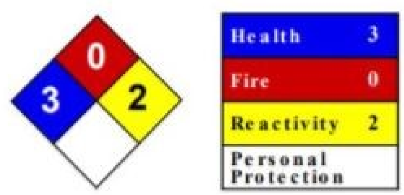
Alkaline Potassium Iodide Azide



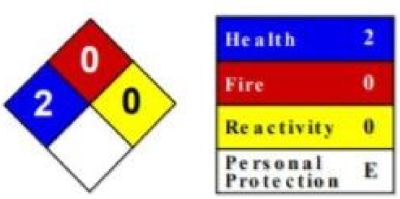
Manganous Sulfate $MnSO_4$



Starch Indicator $C_6H_{10}O_5$



Sulfuric Acid H_2SO_4



Sodium Thiosulfate $Na_2S_2O_3$