

THE EFFECTS OF STUDENT AND SCIENTIST PARTNERSHIPS ON STUDENTS'
UNDERSTANDING OF THE NATURE OF SCIENCE

by

Katherine M. Chesnutt

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Katherine M. Chesnutt

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TABLE OF CONTENTS

INTRODUCTION AND BACKGROUND	1
Teaching Experience	1
Project Background	1
Focus Question	2
CONCEPTUAL FRAMEWORK	2
Nature of Science	2
Student-Scientist Partnerships and the Nature of Science	4
METHODOLOGY	6
Pretreatment	7
Treatment	9
Macroinvertebrate Study Partnership	10
Microhydropower Study Partnership.....	10
Fish Population Study Partnership.....	12
Post Treatment	14
DATA AND ANALYSIS	17
NOS Survey Analysis	17
Science Research Skills Analysis	22
Best Practices for SSPs	27
INTERPRETATION AND CONCLUSION	31
VALUE	38
Understanding of the NOS	38
Strategies for Successful SSPs	40
Expected Outcomes of Students, Teachers, and Partnering Scientists	41
REFERENCES CITED.....	43
APPENDICES	45
APPENDIX A: Student Nature of Science Survey.....	46
APPENDIX B: Student Research Skills Assessment.....	51
APPENDIX C: Nature of Science Student Interview Questions.....	53
APPENDIX D: Preproject Student Survey	56
APPENDIX E: Scientists Expected Outcomes Survey	58
APPENDIX F: Student Post Treatment SSP Feedback Survey	60
APPENDIX G: Scientist Post Treatment SSP Feedback Questionnaire	62
APPENDIX H: Biodiversity Index Calculation Sheet	64
APPENDIX I: Microhydropower Assessment Data Sheet	67

TABLE OF CONTENTS - CONTINUED

APPENDIX J: Electrofishing Population Assessment Background Information	.73
APPENDIX K: Electrofishing Student Reading.....	77
APPENDIX L: Scientist Scavenger Hunt.....	80
APPENDIX M: Fish Population Study Analysis.....	82

LIST OF TABLES

1. Triangulation Matrix16

LIST OF FIGURES

1. Five-number Summary of the pretreatment and post treatment NOS surveys.	17
2. Normalized gain on the NOS Pretreatment and Post treatment Surveys by question number	19
3. Student NOS Interview responses when asked, “could you be a scientist?” by percentage	20
4. Accuracy by percentage on questions eight and twenty on NOS Pretreatment and Post treatment Surveys	21
5. Normalized gain of science research skills by measuring skill	22
6. Five-number summary of the pretreatment and post treatment Research Skills Assessment.....	23
7. Post treatment open-ended responses on the importance of data collection by percentage	24
8. Post treatment open-ended responses on how scientists use data by percentage	24
9. Post treatment open-ended responses on the importance of measuring skills	25
10. Macroinvertebrate study favorites aspects by percentage	26
11. Macroinvertebrate study least favorite aspects by percentage.....	27
12. Microhydropower study favorites aspects by percentage.....	28
13. Microhydropower study least favorite aspects by percentage	28
14. Fish population study favorites aspects by percentage.....	29
15. Fish population study least favorite aspects by percentage	30
16. Learning outcomes and perceptions comparison by percentage.....	31

ABSTRACT

Student Scientist Partnerships (SSPs) were implemented with the purpose of improving students' understanding of the nature of science (NOS). Students participated in three research projects with three different scientists over the course of one semester. Performance on NOS surveys did not show significant improvement as a result of the treatment, but students demonstrated some improvement in research skills. Additionally, teachers and scientists demonstrated an improved understanding of best practices for SSPs and alignment of expected outcomes for SSPs.

INTRODUCTION AND BACKGROUND

Teaching Experience

For the past four years I have been teaching science at Watauga High, a rural school in Boone, NC with 1,380 students. My Honors Earth and Environmental Science class has 30 students, which is larger than the average science class size of 23 students. Although there are few minorities, Watauga High is divided by socioeconomic status with nearly one third of the students from rural county schools while the other two thirds are from Boone, a university town, or the surrounding affluent resort communities (NC Report Card, 2010). The school is in its second year of a “one-to-one” computing program in which all students received a laptop computer at the beginning of the year. The access to technology has significantly improved the transfer of information between teachers and students and increased the amount of resources available for instruction both in and out of class. In addition to new technologies in the classrooms, the school moved to a newly constructed campus for the start of the 2010 school year.

Project Background

In the fall of 2010, the earth science and biology teachers at Watauga High began a partnership with several professors in the biology, ecology, and hydrology departments at Appalachian State University, a public university of 17,000 students located in Boone. The goal of the partnership was to monitor possible environmental impacts of the new high school on Hardin Creek, a small stream on the high school campus. The goal of this partnership was to plan and execute a restoration project that would span several years

involving university professors, graduate students, high school teachers, and high school students. As part of the North Carolina Standard Course of Study for all science classes, students must gain an understanding of the nature of science (NOS) and scientific research. This partnership offered an excellent opportunity to incorporate this standard into other aspects of the curriculum such as hydrology and ecology, outlined in Competency Goal Four which states, “The learner will build an understanding of the hydrosphere and its interactions and influences on the lithosphere, the atmosphere, and environmental quality,” (NCDPI, 2004).

Focus Question

Based on my teaching experience, the NOS is a topic covered in many science classes but not always fully grasped by students. This observation and the establishment of the university partnership led to my initial focus question: How do student-scientist partnerships (SSPs) affect high school students’ understanding of the NOS? I also wanted to see how SSPs affect student performance in science research skills, what strategies work best to foster a meaningful relationship between student and mentoring scientist, and how perceptions of expected outcomes differ among students, teachers, and mentoring scientists.

CONCEPTUAL FRAMEWORK

The Nature of Science

Establishing a fundamental understanding of the NOS along with developing the foundational knowledge, critical-thinking skills, and the ability to apply what has been

learned, are paramount goals in science education (American Association for the Advancement of Science [AAAS], 2009; Lederman, 1999). The nature of scientific research takes many forms, can have contradicting guidelines, and continues to evolve with new developments in technology. For this reason philosophers of science and educators tend to have contradictory definitions of the NOS (Lederman, 1999). The general goals set forth in the *Benchmarks For Science Literacy* by the AAAS and in the *National Science Education Standards* by the National Research Council (NRC) explain that scientific knowledge is continually reevaluated and altered, based on careful observations, unbiased, discovered using both creativity and imagination, and entrenched in social and cultural aspects of life (AAAS, 2009; NRC, 1996; Kitsantas & Peters, 2010; Lederman).

There are many benefits for students, teachers, and society that result from an understanding of the NOS. Students with an adequate understanding may be more adept at problem solving, have heightened interest in science, be more likely to abandon misconceptions about science, and identify scientific processes as a means of gaining scientific knowledge. (Akerson & Abd-El-Khalick, 2003; Kitsantas & Peters, 2010).

The widespread motivation for encouraging the instruction of the NOS is that if students can understand and analyze data in the science classroom, they will become citizens capable of making responsible and informed decisions in a world continually impacted by scientific developments (Lederman, 1999). However, research has shed light on the lack of adequate instruction in science literacy as demonstrated through students' inability to distinguish between science and pseudoscience, and to view scientific issues apart from social issues (Abd-El-Khalick & Akerson, 2004; Kitsantas & Peters, 2010).

Teachers' language, cookbook labs, science textbooks, and standardized tests can all convey misconceptions about the NOS to both teachers and students (Clough & Olson, 2004).

Teachers' use of language in explaining scientific concepts can lead to misconceptions about the NOS. This method of transferring misconstrued knowledge can be exacerbated by the degree of teachers' naivety in this subject. Cookbook labs can indicate to students that science must follow a specific pattern of steps with little creativity or room for further investigation. Science textbooks that present information as facts without explanations of *how* the information was gathered can also further student misconceptions. Furthermore, these misleading instructional practices are used in preparation for a standardized summative assessment based heavily on vocabulary, implying to students that science is a collection of facts and terms (Abd-El-Khalick & Akerson, 2004; Clough & Olson, 2004; Kitsantas & Peters, 2010; NRC, 1996). The development of science skills and an understanding of the NOS have important implications for sustaining a scientifically literate public capable of making decisions based on empirical evidence.

Student-Scientist Partnerships and the Nature of Science

Significant improvements in students' perspectives of the NOS are not easily achieved by verbal instruction (Papert, 1991; Bell, Blair, Crawford, & Lederman, 2003). For this reason research suggests that the NOS and science research skills must be experientially learned by conducting research with the guidance of a mentoring scientist (Hodson, 1993; Barab & Hay, 2001). One method of research instruction for science

classes is through a SSP. SSPs allow the learner to collaborate on real research with a scientist or mentor, and in doing so, experience non-traditional modes of instruction (Sadler, Burgin, McKinney, & Ponjuan, 2010). These partnerships may benefit all members involved. SSPs in scientific research for undergraduate students can increase awareness of jobs available in science fields, encourage students to seek higher degrees in science, and increase student motivation (Downs, 2010; Markowitz, 2004). Engaging teachers in SSPs can enhance teacher understanding of modern science practices as well as improve inquiry-based instruction (Markowitz, 2004; Sadler et al., 2010). Teachers that participated in instructor training for the Global Learning and Observations to Benefit the Environment Program (GLOBE), designed to allow students to collaborate and share data with scientists, demonstrated increased efficacy in environmental science education following a two week training period. Other advantages of SSPs for teachers may include assistance with field instruction techniques, increased content knowledge, and better access to technology (Markowitz, 2004). Benefits for mentors, in the case of graduate and postdoctoral students, included improving professionalism, instructional methods, and communication skills (Dolan & Johnson, 2009).

SSPs are, however, not without fault. Bell et al. suggest that many times mentoring scientists have misconstrued notions about the knowledge gains of their research apprentices and while students do gain *some* knowledge, their core understanding of the NOS, correct or incorrect, remained unchanged (Bell et al., 2003). Although SSPs are not designed to be the central focus of the curriculum, if appropriately executed, they can serve as a beneficial supplement to assessment driven science instruction (Moss, 2003). SSPs must also be designed in such a way that they allow

students to experience the roles of creativity, ambiguity, and uncertainty that occur during scientific investigations, a feat that can be overcome by allowing the time and opportunity for peer review, discussions, and analysis of results (Grindstaff & Richmond, 2008). While most researchers suggest that SSPs can be beneficial to student learning, the most successful partnerships occurred when students participated regularly in the research, were assigned clear learning objectives, built positive relationships with their mentors, and incorporated all parts of the scientific method including defining the problem and analyzing data (Moss, Abrams, & Kull, 1998; Sadler et al., 2010).

METHODOLOGY

In the fall of 2011 I began a semester-long treatment aimed at introducing high school students to the research practices of scientists with the intention of broadening students' understanding of the NOS and science research skills. Under the guidance of three different mentoring scientists, students completed three stream-related projects involving assessments of aquatic macroinvertebrate biodiversity, estimations of hydroelectric power potential, and collection of age class data on local fish populations. Although all the projects involved the stream, they provided a diversity of scientific backgrounds and exposed students to experts in different fields. Students performed research tasks such as defining problems, data collection, and data analysis. Tasks were completed with mentors once a month while supplemental trips to the stream were taken for further observation and data collection. Students were encouraged to solve problems and design stream improvement solutions as partners rather than pupils in the projects.

Students and scientists participated in a variety of data collection surveys designed to measure any changes in NOS ideology throughout the treatment. Pre-treatment collection instruments included a NOS Survey, Research Skills Assessment (RSA), and Interviews (Appendices A, B, and C). During the treatment I recorded observations in a notebook, took photographs, and administered SSP Feedback Surveys to both students and scientists. Post treatment data collection instruments included the NOS Survey, RSA, and Interviews. The research methodology for this project received an exemption by Montana State University's Institutional Review Board and compliance for working with human subjects was maintained.

Pre-Treatment

Prior to any instruction on the NOS, students participated in the NOS Knowledge Survey (Appendix A). This twenty-question survey provided a starting point from which I based instruction on future units as well as provided the mentoring scientists with information about their new research partners. Students were asked to determine if various statements about science were true or false. The results of this survey were analyzed by percentage of correct and incorrect responses by question. The survey was completed during class along with a RSA in which students visited various stations around the room designed to assess skills in each of the following categories: measuring mass, measuring length using standard and metric systems, and measuring velocity given a slope, ball, and timer (Appendix B). Each skill corresponded with a task the students would perform to collect data with the partnering scientists. For example, in the Fish Population Assessment students would measure the mass and length of the collected fish

using the metric system. Likewise, the velocity skill assessment was based around the stream velocity measured and calculated in the Microhydropower Assessment. The RSA results were analyzed by percentage of correct responses in each skill category and later compared to that of the Post Treatment RSA.

A pre-treatment NOS Interview with students was conducted to provide explanations not provided by the survey. The interview questions were modified to address any aspects of the NOS that were not fully addressed by the survey or that were included in the survey, but required further explanation better achieved through conversation (Appendix C). Interviews were conducted with seven randomly chose students. Student responses were typed in a word document, and students were able to read their responses as I typed, allowing some students to read their answers and make any necessary clarifications without probing. Students' answers were collated for trends in overall understanding and misconceptions about the NOS.

Prior to the treatment, students visited the stream to make observations. The goal was to allow them to observe the impaired nature of the stream, and encourage them to take ownership in the projects. All projects were designed with the goal of taking some form of action that could improve the overall health of the stream and riparian ecosystem.

Students worked every three to four weeks with the partnering scientists at the stream site. Prior to each session, students completed a Pre-Project Survey (Appendix D) in which students answered two questions: 1) What do you think you will learn from working with the scientist today? 2) Will your data that you collect today help the scientist do his/her job? Scientists also completed a Pre-Project Survey designed to delineate his or her expected outcomes and challenges as well as determine the scientists'

understandings and interpretations of the NOS (Appendix E). The expected outcomes of students, scientists, and me were later compared to help understand if each party met his or her expected goal of the SSP. I included NOS questions for the scientists' surveys to see if students might align their beliefs to match that of the scientists with whom they worked for each project.

Treatment

Fostering a relationship with mentoring scientists and preparing for outdoor learning were the first elements of the treatment. Scientists interacted with students on several occasions to establish relationships. Students prepared for outdoor learning by composing a class list of safety rules, clothing requirements, and best practices for going outside as a group for each of the partnerships. All students in the class participated in each of the partnership studies and were monitored over the course of the semester.

Macroinvertebrate Study Partnership

The first mentoring scientist was a local agriculture extension agent for water resources. She frequently works with students of all ages around the county, and many students had experienced working with her in either elementary or middle school. Before taking students outside, she gave them a brief lecture about watersheds and demonstrated point-source and nonpoint-source pollution using an Enviroscope Model. Following the short in-class portion, we took the class outside and walked along the stream making observations about erosion, sediment deposition, and overall stream quality. This not only allowed students to begin a relationship with the scientist, but also the stream and outdoor learning.

The next week she returned to collect benthic macroinvertebrate samples in the stream. Students were divided into groups of five or six with about half of them in the stream collecting samples and the other half analyzing and recording data along the stream bank. Students collected organisms by kicking or overturning rocks upstream of seine nets. Students spread the collections on small sheets to count and identify organisms by order using pictures and dichotomous keys. Students recorded the quantity of each species and used this information the next day to calculate a biodiversity index of the stream using the Shannon-Weiner Index as well as an online biodiversity calculator (Appendix H).

Microhydropower Study Partnership

The second mentoring scientist was a Wind and Hydropower professor in Appropriate Technology (AT) at the local university. The AT Department focuses primarily on developing technologies and outreach programs in support of renewable energy resources. One of the programs this department has helped to bring to Watauga High is the Wind for Schools Program in which students take an active role in siting and monitoring a wind turbine on their school property. Because generation of electricity through wind and water both involve turbines, these two energy resources are easily taught together. Students' first interaction with this scientist was through the wind turbine siting activity in which my students determined the best location for a small wind turbine on the school grounds.

As part of the renewable energy unit, students learned different methods of generating electricity from moving water. Because the school is located in the mountains, small scale hydropower, or microhydropower, can be the most effective and least

ecologically invasive form of hydropower. The scientist and a colleague returned several weeks after the wind turbine activity to help with a microhydropower assessment of the stream. Another class joined my class in this activity, providing nearly fifty students the opportunity to collaborate and collect data on the stream. Students' main task was to measure the average flow of the stream. In groups of about ten, students measured average velocity, width, and depth for a ten foot reach of stream using tennis balls, timers, measuring tape, and meter sticks. About half of the students in each group got in the water and about half remained on the stream bank to record and analyze the data. There were four specific jobs outlined in the student instructions: Dropper, Catcher, Timer, and Watcher. These jobs were divided among group members at their discretion (Appendix I).

As students completed the task of collecting data the scientists guided them to areas along the stream that would be easiest to measure, helped as needed with timing and measuring, and explained to them how a microhydropower system could be constructed on this stream. I helped to keep students on task while making observations in my notebook. Due to the large number of students outside that day, most of my time was spent moving between groups answering questions and preventing student misbehaviors.

Students used the data they collected to determine the number of people the stream could support as a water resource as well as the power the stream could produce through hydropower. To calculate power, the scientists helped by providing students with an average measurement for head (vertical drop) using the following formula: Power (watts) = [Flow (gpm) * Head (ft)] / 10. Students completed a data collection sheet and

finished the following day with calculations (Appendix I). Using the power calculations, students later designed a microhydropower system based on their measurements.

Students then researched costs to determine a pay-back period for the system that each group displayed in a student-made webpage on hydropower.

Fish Population Study Partnership

The last partnering scientist, a professor in aquatic biology and fish toxicology at the local university, was unable to come more than one day to work with the class. For this reason, I wanted to make sure students were very prepared for his one-day visit. In preparation this scientist gave me a student handout that outlined what students would be doing and a description of how they could analyze their data (Appendix J). While going over the handout with the students, they shared many misconceptions and reservations about electrofishing, so I had students read an article about how electrofishing works and an article about the importance of measuring fish populations (Appendix K). To foster a relationship with this scientist, students completed a Scientist Scavenger Hunt in which they read and answered questions about his background and current research projects (Appendix L). This allowed students to see pictures of his research and feel more comfortable when they finally met him.

On the day of data collection the students and I met the scientist down at the stream. He had arranged a measuring station at his vehicle on the side of the path about fifty meters from the section of stream in which we intended to collect fish. Upon arrival students gathered around the measuring station and the scientist presented and assigned them, in groups of about five, with specific tasks. The following groups were assigned: *Netters*, netting the fish as they floated to the surface of the water, *Measurement Experts*,

identifying, measuring, and recording the length and mass of each fish collected, *Bucket Couriers*, transporting fish from the electrofishing site to the measuring station, and *Stream Reach Markers*, measuring the reach of stream in which fish were collected. With a class of thirty students, this left about ten students with no specific task or job. I tried to re-assign jobs for these students, but in most cases found that five students were more than enough to complete the task assigned.

The scientist, along with the group of *Netters*, worked their way up the stream reach collecting fish in a bucket. Once a diverse population of fish had been collected the scientist stood on the bank and identified the fish species for the students. As the scientist continued to help collect and identify fish, I was moving between groups trying to mend arguments, curb frustrations, and keep students on task. The class period ended abruptly before any of the measurements of fish had been recorded, and students rushed back to the school. Luckily, the Advanced Placement Environmental Science (APES) class had successfully completed a similar population study the previous week and their data were what my class used to complete the analysis on the following day.

Students used the fish population information collected by the APES class to create age classes or cohorts based on mass and length in a spreadsheet (Appendix M). Students used these age-class graphs to determine trends in the population of fish in the stream. While the data collection was far from successful, students were able to create and analyze graphs created from another class' data set.

Post Treatment Data Collection

Following each session of collaborative data collection, students answered three questions about the research that day in the SSP Feedback Survey (Appendix F):

1. What was the *best* part of working with the scientists today?
2. What was the *worst* part of working with the scientists today?
3. What did you learn from this activity today?

These questions were designed to determine any changes in student confidence in science research skills, best strategies for SSPs, and student perceptions of expected outcomes.

The best and worst responses were placed into three or four categories depending on the project and analyzed by percentage. The response about what students learned was compared to the students' pretreatment answer when asked, "What do you think you will learn with the scientist today?" I tallied and calculated percentages of students whose expected learning outcome met his or her actual learning outcome. A similar comparison was made between these post treatment "learned" statements and the expected learning outcomes of both the teacher and scientist. Percentages were calculated to measure the number of students that met the expected learning outcomes of both the teacher and scientist for each SSP. The scientists also completed a similar SSP Feedback Questionnaire in which they made a best/worst statement based on interactions with the students, anything he or she may have learned from students, and suggestions for improving the partnership (Appendix G). This allowed me to gain a different perspective on best practices, benefits of the partnership, and insight into the scientists' expected outcomes.

Following and sometimes during each lesson that pertained to the SSPs, I made observations in a science notebook. Observations were collected both in class and at the

research site. Entries included reflections on the research process as well as photographs of students and scientists conducting research.

After all of the research projects, I administered the same NOS Knowledge Survey (Appendix A) and conducted post-treatment interviews on the same seven students (Appendix C). The results of the post-treatment NOS Survey were compared to the pre-treatment NOS Survey using a Normalized Gain (g) formula shown below:

$$g = \frac{(\text{post treatment score} - \text{pretreatment score})}{(100 - \text{pretreatment score})}$$

Class average normalized gain values were calculated by averaging individual student g values. I also created a boxplot to compare upper and lower quartiles of student performance as well as score ranges on the pretreatment NOS Survey and post treatment NOS Survey. Additionally, I analyzed the percentage of correct responses by individual question, with particular attention to those questions frequently missed as well notable changes, both positive and negative, in normalized gain values. Post-treatment interview questions were similar to those asked in the pre-treatment interview with some modifications as needed for clarity of answers and to provide elaboration on survey results.

The last data collection technique assessed students' post-treatment research skills. It was identical to the pre-treatment skills test, but also asked students to answer three questions:

1. Why is data collection important to science?
2. How do scientists use data?
3. Do you think measuring skills are important in data collection? Why?

The open-ended responses about data collection were used to help determine student growth in the understanding of the NOS. Student responses were grouped into one of three categories for each of the questions asked and analyzed by percentage.

The pretreatment RSA scores and post treatment RSA scores were compared using the same normalized gain formula listed above. The skills tests assessed the following measuring skills: mass, volume, length, and velocity. Average student performance in each measuring skill area was analyzed and compared by percent accuracy, normalized gain, and boxplot.

Although a lengthy process, the three partnerships provided opportunities to measure the impacts working alongside experts can have on students' understanding of the NOS and scientific research skills as measured through the NOS Surveys, NOS Interviews, and RSA. In addition to these instruments, the SSP Feedback Surveys from both students and scientists provided insight into best practices for continuing and building these relationships, as well as the effectiveness of the projects in meeting the expected outcomes of all parties involved. Data collection sources, used for each of my research questions, are outlined in Table 1.

Table 1
Data Collection Matrix

SSPs and NOS	Pre-treatment NOS survey	Post-treatment NOS survey	NOS Interviews
Performance in Science Research Skills	Pre-treatment Research Skills Assessment	Post-treatment Research Skills Assessment	Teacher Observation
Strategies for SSP relationship	Student and Scientist SSP Pre-Project Survey	Student and Scientist SSP Feedback Surveys	Student Interviews
Perceptions of expected outcomes	Student and Scientist SSP Pre-Project Survey	Student and Scientist SSP Feedback Surveys	Teacher Observations

DATA AND ANALYSIS

NOS Survey Analysis

Data collection centered on the effect SSPs have on students' understanding of the NOS. Of the 19 ninth grade students that completed both pretreatment and post treatment NOS Surveys (Appendix A), the average score on both the pre-treatment survey and post treatment survey was 74.5% correct indicating no change in student understanding of the NOS. The average normalized gain values of individual students indicated a slight decrease in overall growth with a decrease of -0.04 in student performance. The five-number summary in Figure 1 illustrates the changes in student performance of different achievement groups following the SSP treatment.

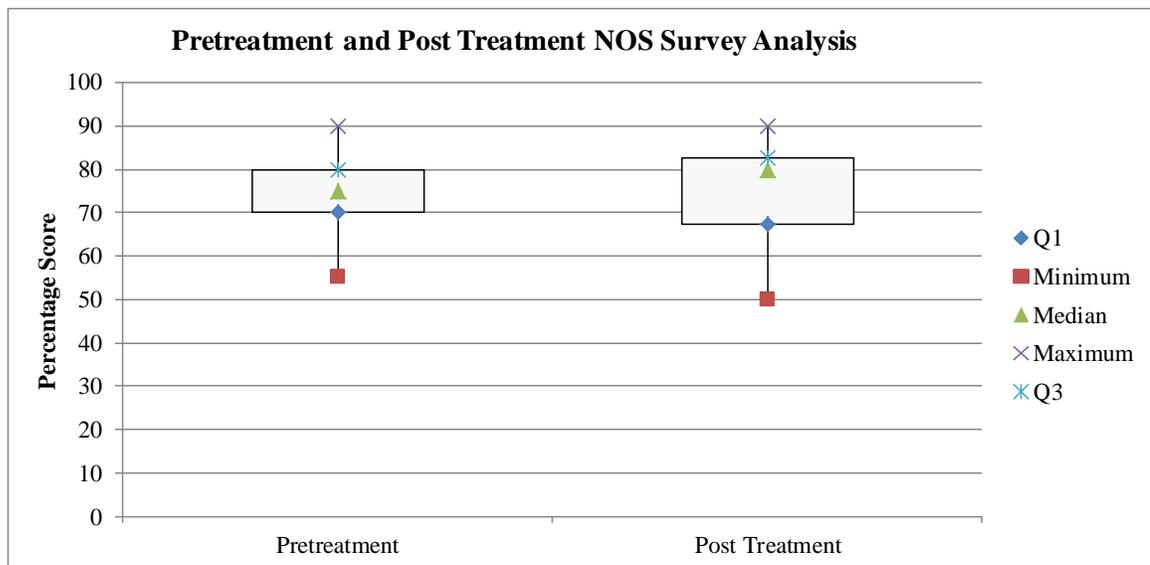


Figure 1. Five-number Summary of the pretreatment and post treatment NOS surveys. The box plot reports the minimum, median, maximum, upper quartile, and lower quartile student scores, ($N=19$).

As illustrated in Figure 1, the minimum score on the pretreatment NOS survey was 55% and the maximum score was a 90%; allowing for a range of 35 percentage

points. The lower quartile of scores ranged from 55% to 70%. The upper quartile of scores ranged from 80% to 90%, and the median score was 75%. In comparison, the post treatment NOS survey results included a minimum score of 50%, a slight decrease from the pretreatment NOS survey and no change in maximum score, allowing for a range of 40 percentage points, slightly larger than the pretreatment NOS survey. The lower quartile scores dropped lower in the post treatment results with a range of 50% to 67.5% while the upper quartile scores increased from 82.5% to 90%. The median increased by five percentage points from 75% in the pretreatment NOS survey to 80% in the post treatment NOS survey.

Further analysis of the pretreatment and post treatment data by survey question indicated specific areas in which students' NOS knowledge increased or decreased following the SSP treatment. As illustrated in Figure 2, survey questions one and two had no change in normalized gain. However, despite this equal normalized gain value, students answered question one, which asked students if science could prove anything, solve any problem, or answer any question, with only 63% accuracy. The misconception that science can solve *any* problem was emphasized further in student interviews in which most students explained that science was the study of "everything" and "how everything works." Question two, which asked students to determine if different scientists may get different solutions to the same problem, was answered with 100% accuracy on both pretreatment and post treatment surveys. One student explained this idea further by saying that "different experiments [in science] show different ways to solve problems." Students demonstrated the moderate gains in questions that addressed scientific knowledge illustrated by their responses on questions six, nine, and eleven,

with normalized gain values of 0.5, 0.6, and 0.8 respectively. In these questions students indicated an increase in understanding of how much about the natural world scientists have yet to discover, how scientists not only prove but also disprove their own ideas, and defining science as more than simply research based on logic and reasoning. Students' performance on the NOS Survey decreased on several questions. Although the normalized gain values decreased in questions thirteen and fourteen in which students were asked to determine if science involves uncertainties and if science can be conducted only by scientists, the percent accuracy on pretreatment and post treatment NOS surveys was above 95%, with all students answering both questions correctly on the pretreatment survey. Four of the seven students that participated in the pretreatment interview expressed the idea the he or she could be scientists. Following treatment, six of the seven students shared this view (Figure 3). Although some students considered themselves scientists, when asked if most doctors and engineers were considered practicing scientists only 47% answered agreed with this statement. Following treatment, however, this outlook was shared by 90% of students.

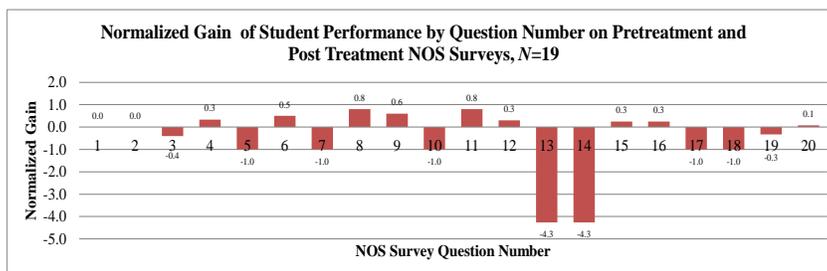


Figure 2. Normalized gain on the NOS Pretreatment and Post treatment Surveys by question number, ($N=19$). See Appendix A for question descriptions.

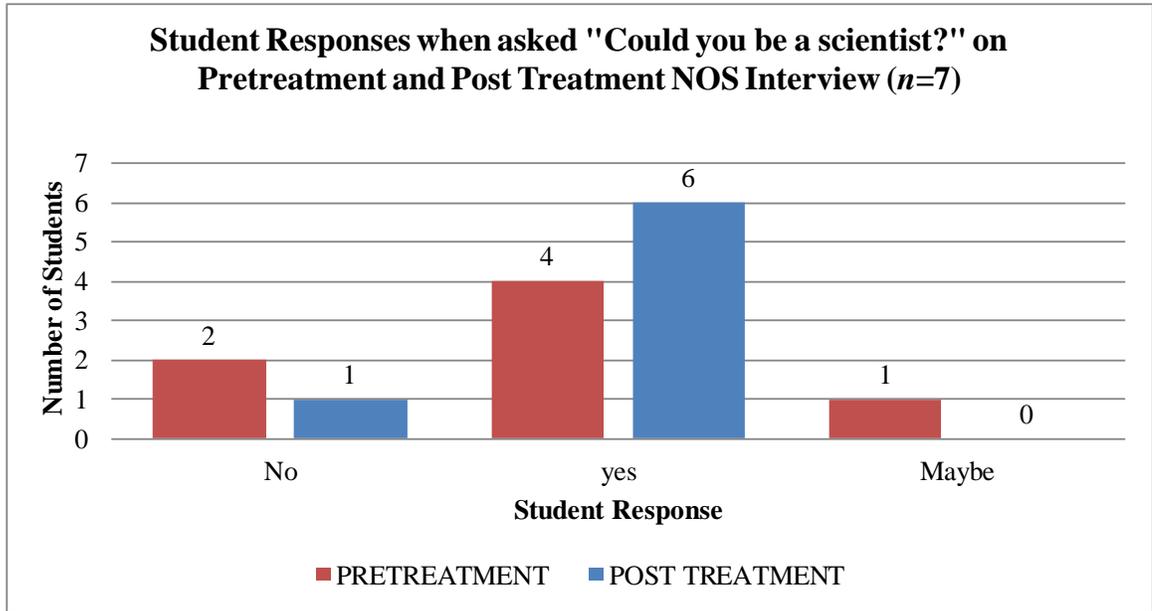


Figure 3. Student responses when asked "Could you be a scientist?" on the pretreatment and post treatment NOS Interviews. Shown by number of student responses of no, yes, or maybe, (n=7).

Students performed poorly on both pretreatment and post treatment when asked to determine if scientific investigations are practiced in a step-by-step method that guarantees the generation of valid knowledge. As illustrated in Figure 4, students answered with 32% accuracy in the pretreatment NOS Survey and 37% accuracy in the post treatment NOS Survey.

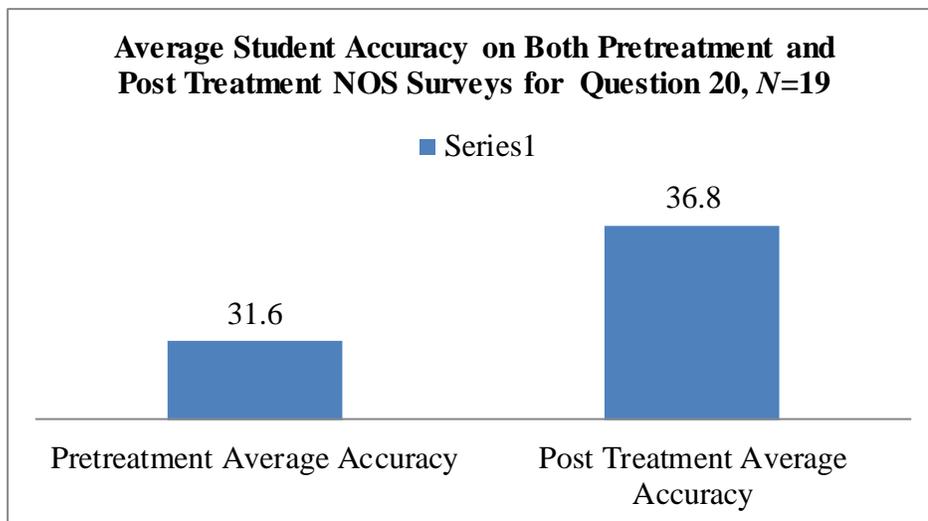


Figure 4. Average student percent accuracy on pretreatment and post treatment NOS surveys for questions in which most students answered incorrectly on both surveys. Question twenty asked students to determine if scientific investigations are practiced in a step-by-step method that guarantees the generation of valid knowledge.

Science Research Skills Analysis

Although the NOS Survey seemed to indicate that the SSPs offered little improvement of students' understanding of the NOS, the RSA provided evidence of some improvements to students' science research skills following the SSP. On the pretreatment RSA students' performed with 53.4% accuracy. Following the SSP, students increased accuracy on the same assessment to 74.6% with a normalized gain of 0.45 as shown in Figure 5. Students demonstrated the most improvement with a normalized gain of 1.0 in measuring volume in milliliters using a graduated cylinder. Normalized gain on measuring length in centimeters decreased by -0.5, with the class average dropping from 89.5% to 84.2% accurate. Another area in which students showed little increase in skill development was measuring velocity with a normalized gain of only 0.16. To accomplish this, students needed to determine the velocity of a ball rolling down a slope. Students

missed this question in some instances due to a lack of understanding of units, with several answers reported incorrectly as $\frac{\text{time (seconds)}}{\text{distance (meters)}}$ rather than the correct $\frac{\text{distance (meters)}}{\text{time (seconds)}}$ even though the instructions to the question specifically asked for the latter.

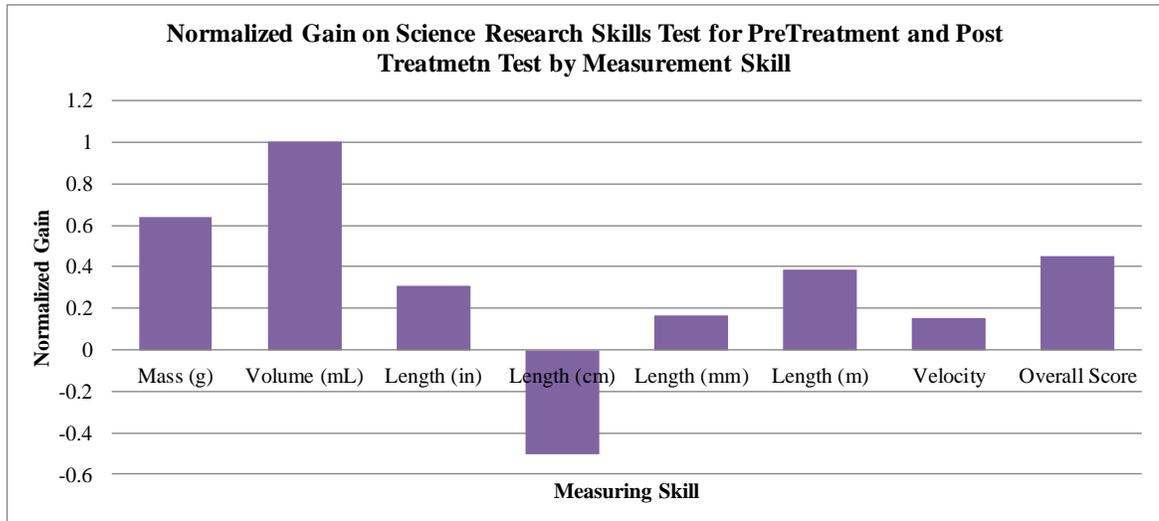


Figure 5. Normalized gain of class averages on Pretreatment and Post Treatment RSA by measuring skill.

The five-number summary in of the pretreatment and post treatment RSA performance indicated an overall improvement in student performance. The pretreatment upper quartile student scores ranged from 71.4% to 100%. All students in the upper quartile scored 100% on the post treatment RSA (Figure 6). The median score also improved from 42.9% in the pretreatment RSA to 83.3% in the post treatment RSA. While the minimum score improved only slightly, from 0% to 33.3%, the middle fifty percent of students in the post treatment RSA performed as high as the upper quartile of students in the pretreatment RSA (Figure 6).

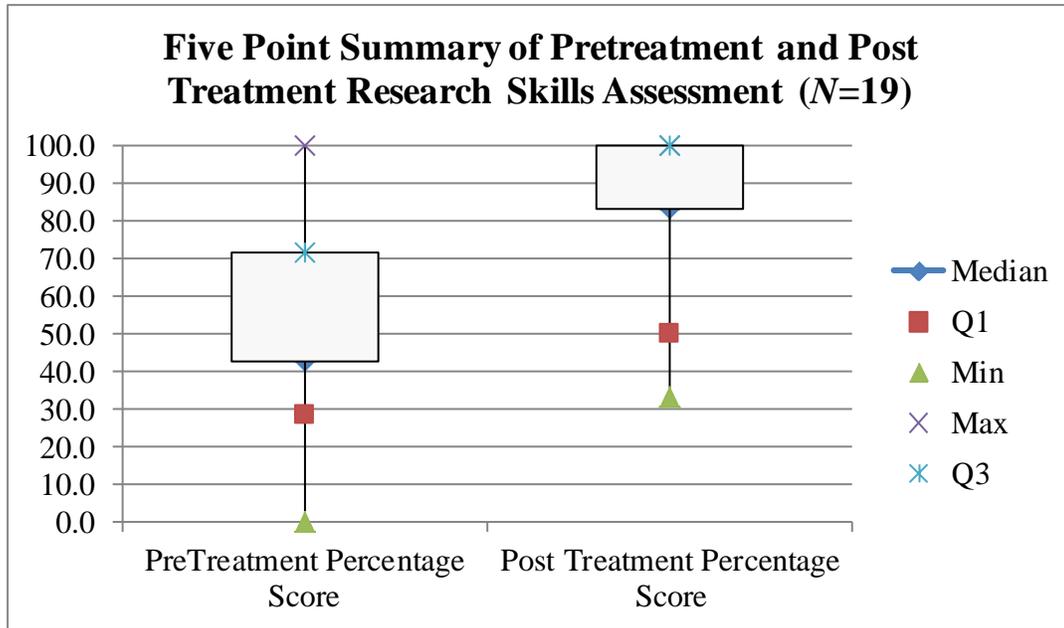


Figure 6. Five point summary of the pretreatment and post treatment Research Skills Assessment. The box plot reports the minimum, median, maximum, upper quartile, and lower quartile student scores, (N=19).

On the Post Treatment RSA, students shared his or her feelings about the importance of data collection in science. All responses, which were designed to be open-ended, fell into one of three categories for each question. In these questions, most students, 61%, indicated that data were used by scientists to provide evidence for conclusions or prove a hypothesis (Figure 7). Not all students held this view, however, with 17% stating that data collection was needed for gathering information, and another 22% explaining data collection was needed for experiments.

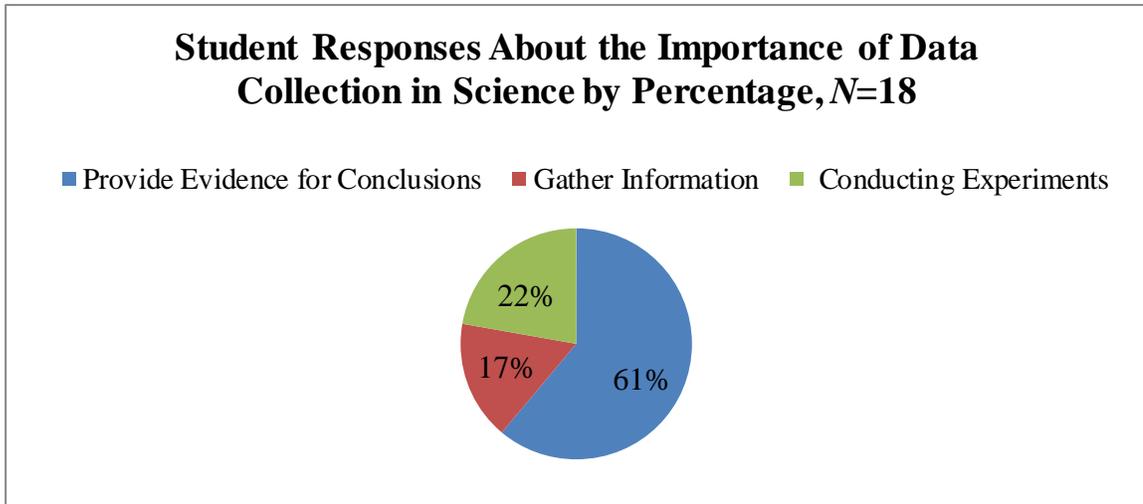


Figure 7. Student open-ended responses on the Post Treatment Science RSA about the importance of data collection in science by percentage, ($N=18$).

When asked how scientists used data, most students, 72%, indicated that scientists use data to provide evidence for conclusions shown in Figure 8. Similar to the previous question on the survey, 22% stated that scientists use data to gather information, and a few students, 6%, stated that scientists use data for conducting experiments.

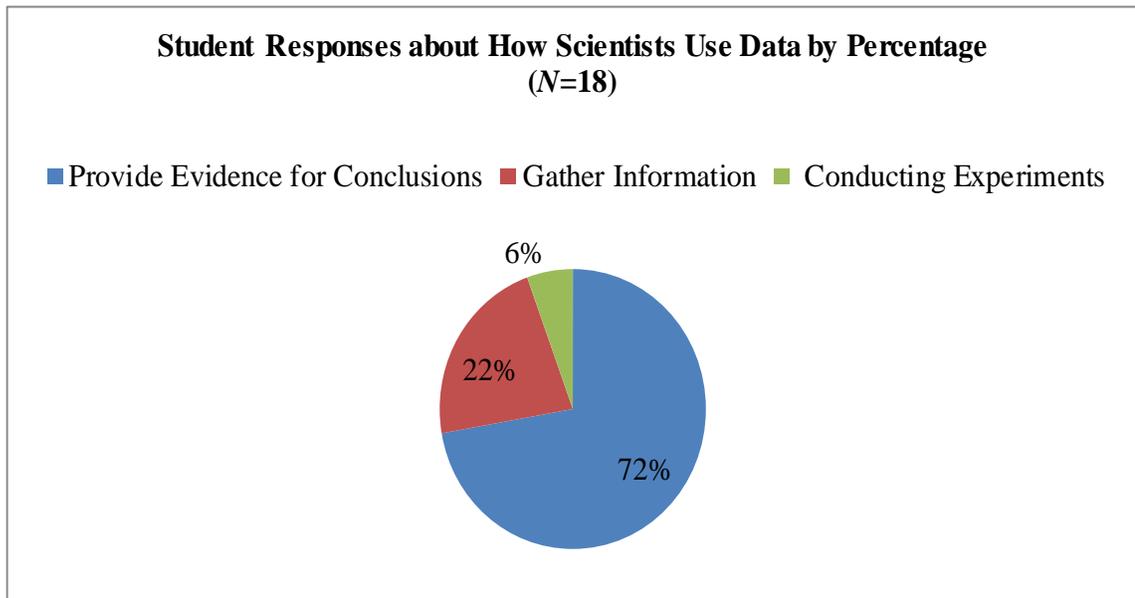


Figure 8. Student open-ended responses on the Post Treatment Science RSA about how scientists use data by percentage, ($N=18$).

In the third and last open-ended response on the RSA, students explained why measuring skills are important in science. In Figure 9, 39% of students answered that measuring skills were necessary to gather “correct” information. One student supported this claim by explaining that without proper measuring skills “your data could be incorrect,” and another stated that measuring skills are important because “if you are not precise you can get it [data] wrong.” These statements indicate that following the SSP treatment, students gained a better understanding of the importance of measuring skills in the collection of useful data.

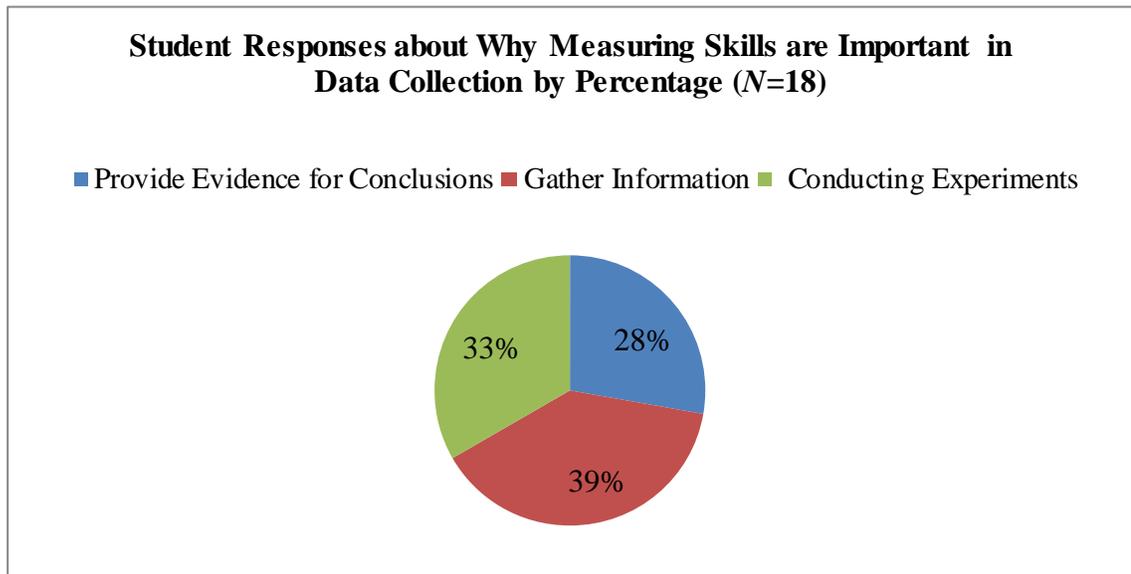


Figure 9. Student open-ended responses on the Post Treatment Science RSA about why measuring skills are important in data collection by percentage, (N=18).

Best Practices for SSPs

The SSP Feedback Surveys administered to both students and scientists helped to determine best practices for SSPs. With this instrument, students shared favorite aspects of the partnership, least favorite aspects of the partnership, and what he or she learned

from the partnership. In the macroinvertebrate study, even though 31% of students did not respond, over half, 53%, shared that observing and collecting the organisms was the best part of the partnership and 16% of students thought the creek or water was the best part (Figure 10). When asked what he or she disliked, 42% of student responded with “nothing,” which leads me to believe that these students, for the most part, enjoyed everything about the SSP. Some students did share their least favorite part of the SSP with 27% disliking the cold water in the creek and 21% disliking the walk to and from the creek (Figure 11).

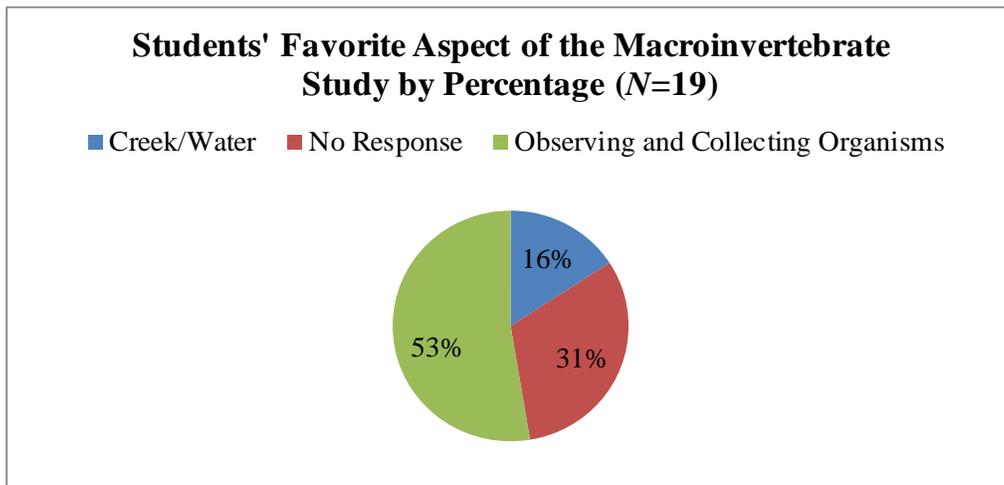


Figure 10. Student open-ended responses when asked his or her favorite aspect of the macroinvertebrate study by percentage, (N=19).

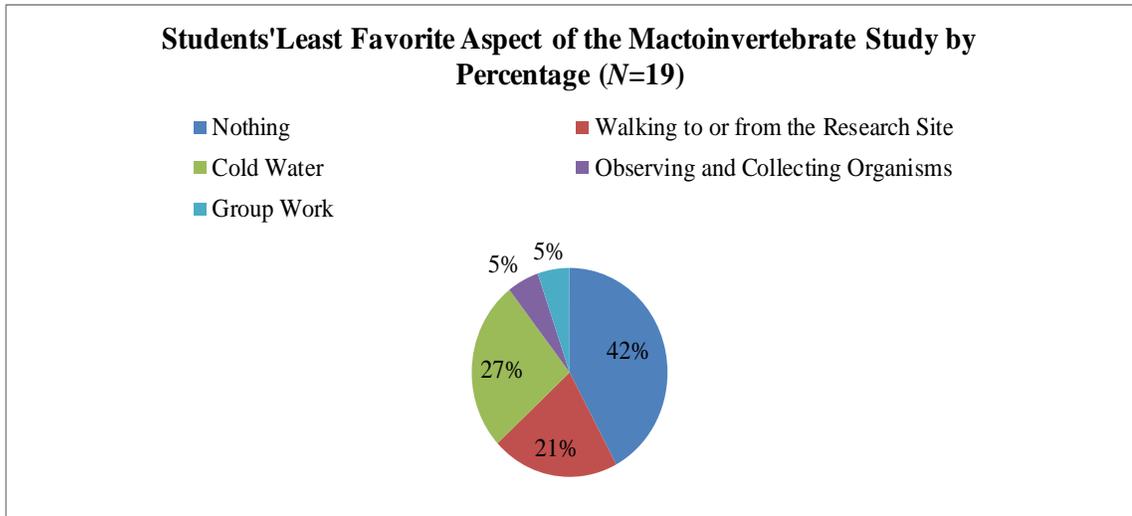


Figure 11. Student open-ended responses when asked his or her least favorite aspect of the macroinvertebrate study by percentage, (N=19).

On the microhydropower partnership students' feedback was associated with one main factor: water. This part of the research project divided the class nearly in half with 47% of students listing getting in the water as a favorite and 53% listing cold water as a least favorite (Figures 12 and 13, respectively). Some students fell into both of these categories, for example, six students' favorite part included getting in the water, but these same students found it was too cold to fully enjoy, and therefore listed cold water as his or her least favorite aspect. Similar to the macroinvertebrate study, walking to and from the creek was a commonly held dislike about the project with 21% of students listing this as his or her least favorite part.

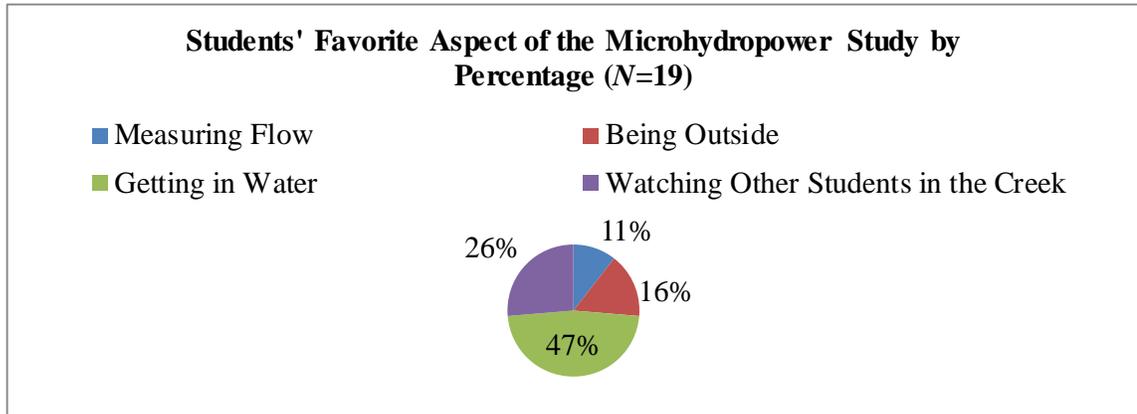


Figure 12. Student open-ended responses when asked his or her favorite aspect of the microhydropower study by percentage, (N=19).

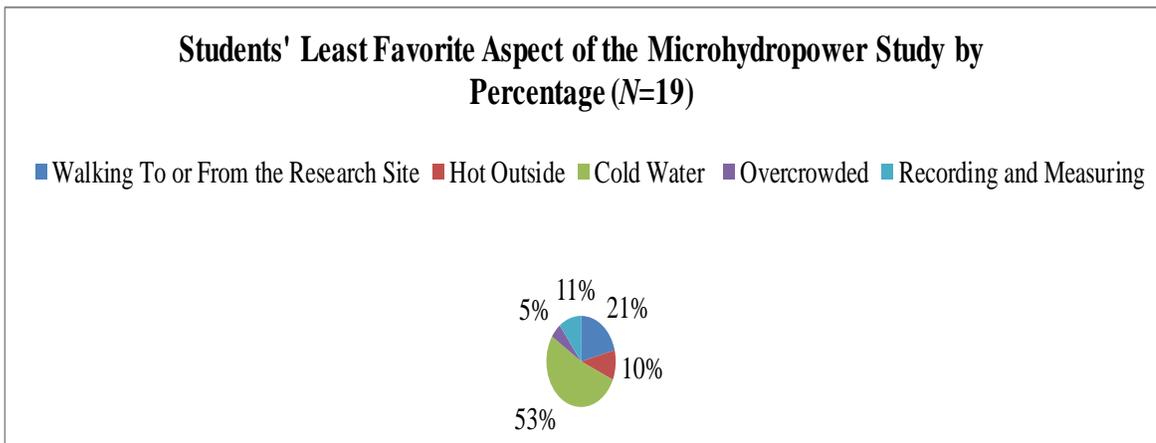


Figure 13. Student open-ended responses when asked his or her least favorite aspect of the microhydropower study by percentage, (N=19).

The fish population study feedback indicated that the class' two favorite aspects of the partnership included collecting and observing fish. These factors were also the main tasks of the research partnership as shown in Figure 11 in which 47% of students listed collecting and observing fish as their favorite aspect of the partnership and 37% of students listed collecting data and learning about the fish as their favorite aspect of the partnership. Although water was not mentioned as a favorite aspect of the partnership, as in the other SSPs, going outside was listed by 16% of the students (Figure 14).

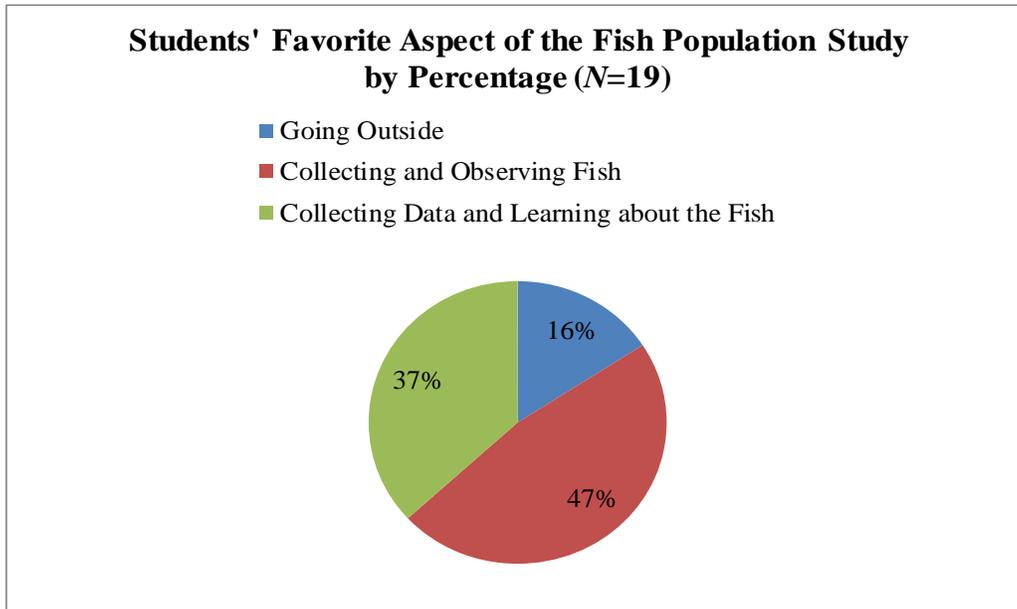


Figure 14. Student open-ended responses when asked his or her favorite aspect of the fish population study by percentage, (N=19).

The class provided the most diversity of responses when asked to list a least favorite aspect of the fish population study. The greatest number of students, 26%, listed harming the fish as their least favorite aspect but time limitations and getting wet, dirty, or hot were both listed by 21% of student, and 16% of students to listed “not being able to participate as much as I wanted,” (Figure 15).

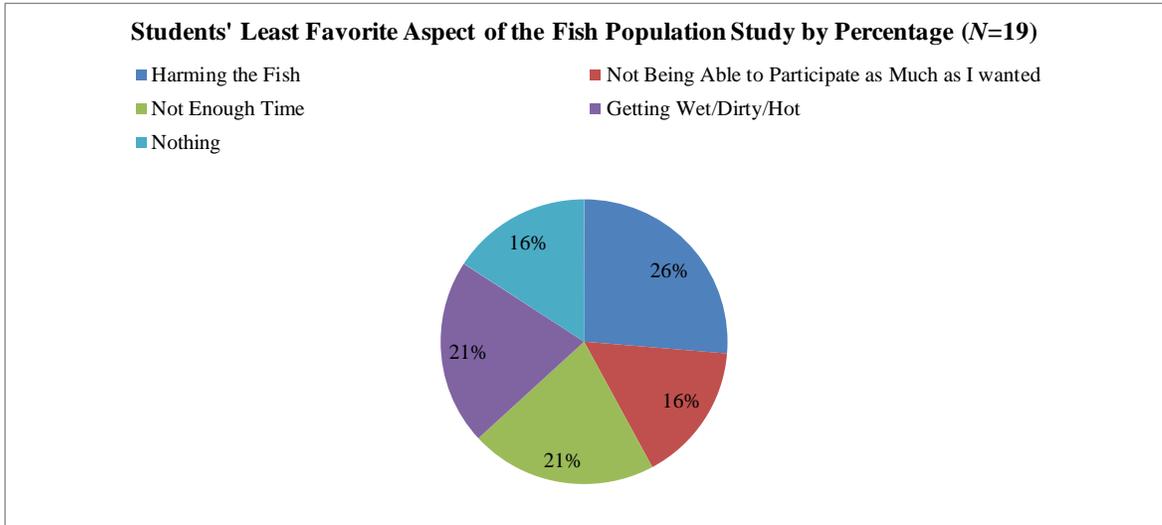


Figure 15. Student open-ended responses when asked his or her least favorite aspect of the fish population study by percentage, (N=19).

Overall the SSP Feedback Surveys indicated that students' favorite aspects of both the macroinvertebrate and fish population studies dealt in some way with the learning goals set forth by both the teachers and the scientists. As part of the Pretreatment NOS Survey, students shared what he or she expected to learn. Scientists and teachers shared a similar goal. These learning goals were compared to the students' responses when asked "What did you learn from the research project?" and analyzed to determine the percentage of students that met the learning goals set forth by the student, teacher, and scientist. As shown in Figure 16, 53% of students met the learning goals expected of themselves, teachers, and scientists for the macroinvertebrate study and 63% met these goals for the fish population study. Less successful in meeting learning goals was the microhydropower research project in which only 16% of students met the scientist's learning goal (Figure 16).

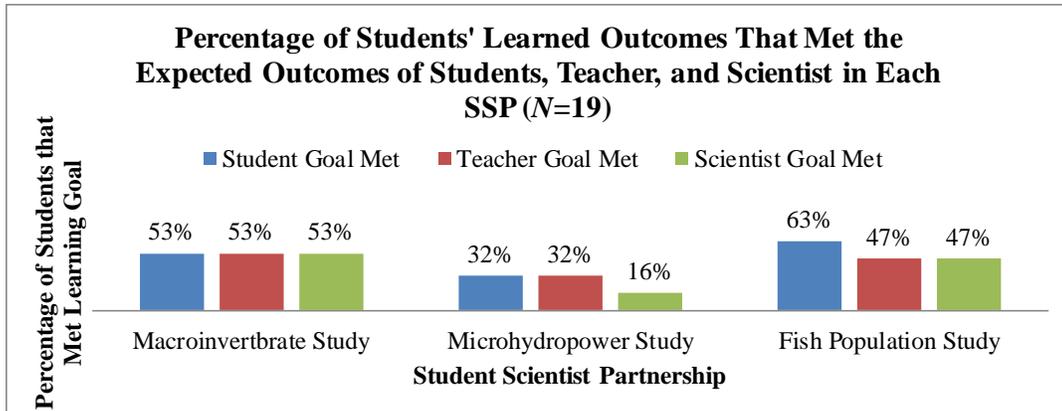


Figure 16. Percentage of students that participated in the study and that met his or her expected learning goal as set forth by the student, teacher, and scientist in each of the SSPs, (N=19).

INTERPRETATION AND CONCLUSION

Student performance on the NOS Surveys indicated very little change in overall improvement of understanding of the NOS as a result of the SSP. The highest performing students seemed to benefit most with the upper quartile of students increasing from 80% to 82.5%, but the lowest performing students showed a decrease in understanding of the NOS following the treatment (Figure 1). The lack of improvement on the part of the lower performing students may have resulted from distractions that may be present in an outdoor learning environment. The areas in which students demonstrated growth, albeit minimal, in understanding the NOS included the following concepts: scientists have not yet discovered many things, science practices are not limited strictly to scientists, scientific practices require scientists not only prove but disprove their own ideas, and science is not based on logic and reasoning alone.

Students worked with scientists to collect information that was unknown to both the student and the scientist. This illustrated to the students that scientist are continually trying to gain information about a specific topic because even the scientists, as experts in

their fields, do not have all the answers. This exposure to an expert in a specific field that still does not have all the answers may help students feel more comfortable when he or she does not know the answer to a problem and may encourage the student to devise a way to find the answer rather than try to ask for help. This also may have helped demonstrate to the students that scientists are not always correct in their findings or conclusions and can prove hypotheses as frequently as disprove them. As active participants in the studies I think the students realized that students and most other individuals are capable of collecting data and contributing to the scientific process.

The SSP improved students' understanding about how scientific knowledge is gained. For example, prior to the SSP most students held the idea that science was based primarily on logic and reasoning. While this is not entirely incorrect, science includes processes such as measuring, creativity, and imagination that the students experienced during the treatment that likely led to this shift in understanding.

Despite very little increase in the overall average scores on the NOS Surveys, the interview responses indicated contrasting information, particularly involving question 20 on the survey, which asked students to determine if scientists follow a step-by-step procedure to generate valid knowledge. The SSP may not have helped students understand that scientific knowledge is not obtained through a step-by-step procedure. Most students answered this survey questions incorrectly on both pretreatment and post treatment surveys (Figure 4). Although students' responses were most likely influenced by prior experience with laboratory exercises, the research projects students conducted alongside the scientists may have led students to continue to answer this question incorrectly. During each investigation scientists guided students through specific data

collection techniques. Although it was emphasized that the data collection techniques would provide for better comparison of class data, students may have interpreted these processes as the “steps” scientists always use to generate valid knowledge. I do not believe that the partnership allowed enough student-guided research, and I would be interested to address this topic in future SSPs.

Although she answered question twenty incorrectly, one student demonstrated understanding of this concept during the post treatment NOS interviews by explaining that when “something didn’t work in the experiment we had to change it.” Other students provided knowledgeable explanations in the pre-treatment interview when asked if scientists use imagination and creativity in their investigations. One student explained that scientists need creativity “because there isn’t just a chart that says for weather experiments do them this way and for ocean do them another way. They have to figure out an experiment that tests for the variable they’re trying to learn about.” Another student suggested that scientists need creativity and imagination, “because if you’re trying to solve unknown mysteries you have to use your imagination to imagine what the answer could be.” In the post treatment interviews students provided similar responses with one student explaining that scientists needed creativity in their experiments because if “everybody had the same experiments they might have the same outcome, but if they have different experiments it shows different ways to solve problems.” This illustrates that despite poor performance in this area of the survey, students recognized, both before and after treatment, that science requires creativity and imagination. Additionally, it is likely that most of students’ experience with science activities involved recipe style labs in which students follow specific steps to complete an experiment rather than designing

or investigating the problem or question independently. For this reason, I was not at all surprised to see that over half the class marked question 20 as a true statement. A disconnection between student explanations and survey responses may have resulted from the survey being inadequate in measuring the understanding of the NOS compared to the interview which provides much more information about what the students know and how they feel. For example in the NOS surveys students had only two options, true or false, for answers. This required students to take a stance with no room to waver in their responses. In contrast, during the interviews students provided answers such as “kind of,” “sort of,” and “maybe,” when asked a similar question, but because of probing for examples students tended to talk themselves through to the correct answer. Changing the phrasing of the survey question to better align with the interview question may help improve this issue in future experiments.

Overall the SSPs may not have helped students gain knowledge about the NOS but it may have exposed students to careers in science. One student mentioned that he had a “better understanding of what scientists do,” and another mentioned that she “might be interested in getting a job” similar to that of the scientist from the macroinvertebrate study.

In comparison to growth in understanding of the NOS, students demonstrated stronger gains in science research skills. Not only did students’ performance on the RSA improve following treatment, but during the post treatment interviews students explained that scientists needed data to support claims and even mentioned “reliable data collection,” as an important aspect of experimentation. During the SSPs students conducted a series of data collection techniques that may have helped improve student

performance on the post treatment RSA. The overall responses about the importance of measuring skills and data collection in the post treatment RSA indicated that while students may have improved their ability to collect information there was still some uncertainty about how data could be used to solve problems. The explanation that data collection is needed for gathering information indicates that students may have misunderstood that while data collection is necessary to gather information, the end result of that information is used to answer a question or solve a problem. Likewise, the explanation that experiments need data rather than produce an environment in which data can be collected, indicate that students did not fully understand this component of the NOS. While the use of data to gather information and conduct experiments could be explained and further defended as correct responses, the idea that scientists use data to gather information most likely indicate that students misunderstand what data are or how data are gathered. In the interviews students provided some evidence that he or she understood that data were necessary to provide evidence to support an idea. For example, some students explained that in order to make a scientific claim the scientist would need “data,” “reliable information,” and “proof.” Not all students shared this point of view, with one student claiming a scientist would need “DNA” to provide evidence to support an idea. This student may have confused scientific evidence with genetic evidence in DNA that may be used to support scientific claims. Additionally, the five-number summary of the pretreatment and post treatment RSA indicated that while the treatment may not have improved the research skills of the lower quartile, it was effective for the middle and upper performing students (Figure 6).

Through the SSP feedback cards I gathered information to help determine best practices and ways of improving the SSPs. Although in some instances students had no major complaints, many of the aspects of the research projects students disliked involved being uncomfortable or the quarter-mile walk from the school to the research site. Student responses about comfort included comments about getting wet, being too hot, or getting dirty. Although I tried to avoid these issues by providing students advanced notice about the days and times we would go outside, some students will forget or come ill-prepared regardless of the advanced notice. Providing students with clothes, water shoes, and a water cooler at the research site may help avoid these problems. Although students mentioned that going outside was a favorite aspect of these research projects, walking outside was mentioned on feedback cards as a major dislike of each SSP. The walk to the creek includes trekking across campus and down a fairly steep incline to the creek. The path is paved most of the way except the last 50 meters down a fairly steep but wide gravel road. I believe this uphill hike on the return trip, fresh on each student's mind as he or she completed the feedback card, is the reason many mentioned the walk to and from the school as their least favorite aspect of the project.

In speaking with the scientist following the research projects there were several areas in need of improvement. Most notably, time was an issue in all projects. Because these scientists also have other jobs, it is difficult to get them to come more than one day. This inhibits scientists from easily participating in long-term projects. Another area in need of improvement included how the students managed and used equipment. Students used tape measures, balances, waders, water shoes, and meter sticks provided by the scientists, and the scientists, at the end of the class period, were left with a large pile of

wet supplies. Most students will be courteous of others' equipment if reminded, but without prompting or specific instructions on how to return equipment, these supplies can be easily abused.

Lastly, scientists complained about disinterested or unmotivated students. As with any class, these students are the most difficult to engage, and during outdoor activities that have little close supervision, will often sit, talk, sunbathe, splash others with water, or refuse to participate. This was most notable during the microhydropower study and the fish population study in which there not enough jobs available for all the participants, leading 16% of students in the fish population study SSP Feedback Survey to list "not being able to participate as much as I wanted," as the students' least favorite aspect of the partnership (Figure15). While these students are in the minority, each of the scientists combatted this at some point during the partnership.

The perceptions analysis indicated if students achieved the learning outcome or goal set forth by the partnering scientist and me. Although the least successful in collecting data, the fish population study provided the greatest percentage of students that listed a learning outcome that coincided with one or more of the learning objectives set up by the teacher and scientist prior to the study. Because we spent several class periods in preparation for the study, students most likely had a better understanding of the purpose of this project with 63% of students who met his or her learning goals (Figure 16). This preparation time may have allowed students to gain a better understanding of expected learning outcomes of the teacher and scientist as indicated by the 47% that met the teacher's and scientist's learning goal.

In contrast, the microhydropower project provided students with the most data, but the lowest percentage of students that met the learning goals established by the teacher and scientist. Although the Microhydropower SSP coincided with the unit on renewable energy, students did not complete as in-depth a preparation for this partnership, and did not gain as much from the experience. I think the students would be more likely to understand the data they collect with better preparation with regard to the purpose, process, and applications of the data they collect.

In the macroinvertebrate study about half the class, 53% met the expected learning goal for the student, teacher, and scientist (Figure 16). Although this is an improvement from the microhydropower project, some student responses indicated that he or she gained little or even incorrect knowledge about the health of the stream. Based on the data collected and analyzed by the students, the stream was considerably impaired in comparison to similar streams in the area; however, a few students explained incorrectly that he or she learned that the stream “had lots of organisms” and “was healthy.” While this comment does not represent the entire class, it does indicate areas in need of improvement.

VALUE

This research project helped me establish a baseline for my students’ understanding of the NOS, strategies for SSPs, and perceptions of expected outcomes for all participants in research projects. Information gained from this study will help guide my instruction as I continue to partner with these scientists to collect data for stream monitoring and restoration purposes while maintaining an ongoing evaluation of the

affects SSPs have on students' understanding of the NOS, best strategies for SSPs, and expected outcomes of students, teachers, and partnering scientists.

Understanding of the NOS

The SSPs provided some exposure to problem solving skills and measuring skills necessary for carrying out scientific experiments, but I think the students understanding of the NOS might grow more from conducting student-designed labs rather than carrying out a task taught by a scientist. I also think these projects may have been more effective if the students spent more time working alongside the scientist and in smaller groups. The approach taken in this research project was to expose as many students as possible to the opportunities available. However, I think it would be most effective to allow a select group of students the opportunity to go into to more depth in the research area.

Evaluating students' understanding of the NOS can help teachers plan and coordinate best curricular strategies. Although this specific research project did not indicate significant gain in student knowledge of the NOS as a result of the treatment, it did provide much insight into what students know about the NOS and related science research skills. This study also illustrates how difficult it is to successfully deliver instruction on the NOS. Surprised by how little my students knew about the NOS, I will assuredly incorporate it into more of my lessons in future courses.

One future research opportunity may be to use a SSP to demonstrate to students the differences in laboratory science and field science. Although similar, as both would include collecting information to answer questions about the natural world, the field science data collection may require energy and athleticism that may appeal to some

students. In contrast, this same outdoor experience could be a turn off for others. The comparison may help encourage students to find an area of interest by allowing for exposure to greater breadth in research opportunities.

Strategies for Successful SSPs

Strategies for SSPs developed from these activities include preparing students for data collection techniques and tools, instilling student ownership in the project, and illustrating to students the significance and usefulness of the data collected during the project. In all projects students may have been more successful in collecting useful and accurate data by practicing the skills of data collection before each study. For example, in the macroinvertebrate study I believe that students may have benefitted from the prior use of a dichotomous key, familiarity with species found in the stream, and collection of organisms using sein nets. Similarly students would have likely benefitted from practicing measuring water velocity using tennis balls prior to the microhydropower project, and proper use of a balance with a live or moving specimen would have been particularly helpful prior to the fish study.

Although students visited the stream prior to treatments to make observations on its impaired nature, some students were not able to make a connection between the data collected during each project and its influence on improving stream health. In several instances students were not engaged in the activities and failed to use the data to accurately portray or explain the results. To improve upon this I think more class time following the projects could be spent reflecting, discussing, and making data driven decisions about the stream and plans for restoration. This could not only provide students

with more emphasis on the importance of data collection, but also increase student ownership in the process as well as connect the data collection process with decision making and implementation of stream restoration activity

Expected Outcomes of Students, Teachers, and Partnering Scientists

Students' expected outcomes for each research project lacked specific goals but due to their generality were met in some way for most students on each project. For example, many students predicted they would learn about the organisms in the stream while working on the macroinvertebrate project. Although most students' responses aligned with this goal in the SSP Feedback Survey, some students demonstrated very little gain in knowledge about the stream health as a result of the project. I think this deficiency could be improved upon by presenting students with questions or goals that their data should be able to determine at the end of the project. While students were told to collect data, it may not have been as clear to them *why* they needed to collect the data.

Teacher and scientist expected outcomes were specific, closely aligned, and were aided by regular communication. For example, in the microhydropower project, I guided students through most of the project because I had few if any goals provided by the partnering scientist. On the other hand in the macroinvertebrate and fish population projects scientists shared clearly outlined procedures and learning objectives for the students. Clear communication between teachers and scientists can prevent sending students mixed messages about project procedures. To improve upon this it is important to share goals about what each party wishes to accomplish from the project, and what

students should learn from the project. Making the shared goals apparent to all parties involved will help keep the purpose of the project clear to all participants.

I found sharing the instructional process with partnering scientists an overall positive experience. It provided access to instructional materials and field research equipment that would not otherwise be available for my class to use, allowed students to learn information from a source other than their teacher, and encouraged students to participate in activities that challenged them to collect and analyze data. In addition to these positive attributes, the study provided information that will undoubtedly shape my future teaching practices, not only for SSPs, but also everyday classroom exercises.

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APPENDICES

APPENDIX A

STUDENT NATURE OF SCIENCE SURVEY

Appendix A

Nature of Science Survey

Answer "T" (True) or "F" (False) in the appropriate column.

#	Statement	Your Answer	Correct Answer
1	Science can prove anything, solve any problem, or answer any question.		
2	Different scientists may get different solutions to the same problem.		
3	Science is primarily concerned with understanding how the natural world works.		
4	Science can be done poorly.		
5	Science is primarily a method for inventing new devices.		
6	Scientists have solved most of the major mysteries of nature.		
7	Science can study things and events that happened in the past, even if there was no one there to observe the event.		
8	Most engineers and medical doctors are practicing scientists.		
9	Scientists often try to disprove their own ideas.		
10	Scientists can believe in God or a supernatural being and still do good science.		
11	Any research based on logic and reasoning is scientific.		
12	Scientific knowledge and investigation are influenced by scientists' beliefs, race, gender, prior knowledge, nationality, religion, training, experiences, and expectation.		
13	Science involves dealing with many uncertainties.		
14	Science can be conducted only by scientists.		
15	Something that is "proven scientifically" is considered by scientists as being a fact, and therefore no longer subject to change.		
16	Science involves human imagination and creativity.		
17	Disagreement between scientists is one of the weaknesses of science.		
18	Science is based, at least partially, on observations of the natural world.		

19	Science is practiced separate from social and cultural influences.		
20	Science investigations are practiced in a step-by-step method that guarantees the generation of valid knowledge.		

Modified from the following sources:

Steven M. Dickhaus, Lederman, N. G., Abd-El-Khalick, F., Bell, R. L., & Schwartz, R. (2002).

Views of nature of science questionnaire: Toward valid and meaningful assessment of learner's conceptions of nature of science. *Journal of Research in Science Teaching*, 39(6), 497-5

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<<http://www.science.oregonstate.edu/bi10x/bi102/natureofsciencesurvey.htm>>

2)

APPENDIX B

STUDENT RESEARCH SKILLS ASSESSMENT (RSA)

Appendix B

Name: _____ Date: _____ Period: _____

Science Measuring Skill Pre-Test

This is a measuring skill PRE-TEST which means you will not be penalized for your performance. This will be used by your instructor to determine which skills you know and which skills you may need to practice. Please answer every question and try your best!

Station A:

1. Using the balance provided, measure the mass (in grams) of the object. ___

Measurement Units

Station B:

2. Using the graduated cylinder record the volume (in milliliters) of the liquid.

Measurement Units

Station C:

Using your ruler, measure the length of the line below in each of the units listed.



3. _____ inches

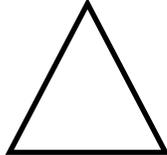
4. _____ centimeters

5. _____ millimeters

6. _____ meters

Measure the area of the following shapes in square centimeters (cm²).

7.



8.



Station D:

9. Using a timer and measuring tape, calculate the velocity or speed (m/sec) of *rolling* (NOT PUSHING) the ball down the slope. You may draw a diagram to demonstrate your calculations. PLEASE SHOW YOUR WORK!

Measurement

Units

APPENDIX C

NATURE OF SCIENCE STUDENT INTERVIEW QUESTIONS

Appendix C
NOS Student Interview Questions

1. What is science?
2. How is science different from the other subjects you study like math and history?
3. What does a scientist do?
More probing follow-up questions:
 - a. Why do they do _____?
 - b. Do *all* scientists do _____?
 - c. Do you think *you* could do this?
4. Do you know any scientists?
 - a. Do you think that doctors and engineers are scientists?
 - b. Why or why not?
5. In order to predict the weather, weather persons collect different types of information. Often they produce computer models of different weather patterns.
 - a. Do you think weather persons are certain (sure) about the weather patterns?
 - b. Why or why not?
6. Scientists try to find answers to their questions by doing investigations / experiments. Do you think that scientists use their imagination & creativity in their investigations /experiments? **YES or NO?**
 - a. If **NO**, explain why.
 - b. If **YES**, in what part of their investigations (planning, experimenting, making observations, analyzing data, interpretation, reporting results, etc.) do you think they use their imagination and creativity?
 - c. Give examples if you can.
7. Do you think that high school students can do scientific investigations?
 - a. Why or Why not?
8. Scientists have never seen dinosaurs, yet most people and scientists believe they existed. Why is this?

1. What do scientists need in order to make claims about information?
2. Could you make a scientific claim?
9. What kinds of things could a scientist and a high school student research together?

Modified from an interview available at this website:

http://region11mathandscience.org/PLCFacilitators/documents/VNOS_D.pdf

APPENDIX D

PRE-PROJECT STUDENT SURVEY

Appendix D

NOS Pre-Project Survey: Macroinvertebrates

Name:

Date:

Period:

Student Pre-Project Survey: Answer the following BEFORE going to the creek with Wendy.

1. What do you think you'll learn from going outside with Wendy today? _____

2. Will your data collected today help Wendy do her job? (circle one) **YES** or **NO**
3. Why?

Using the scale below, how would you rank the following statements?

1 = strongly agree 2 = agree 3 = disagree 4 = strongly disagree

1. _____ I think my data is important to Wendy and other scientists that may be researching this stream.
2. _____ I have the research skills needed to collect useable scientific data.
3. _____ My classmates have the research skills needed to collect useable scientific data.
4. _____ My data can help solve problems in the real world.
5. _____ I can analyze data to help solve problems in the real world.
6. _____ I can complete most tasks with some instruction and guidance.
7. _____ All groups today should get similar data about the stream.
8. _____ My data today will be collected based on observations.
9. _____ My data collection will not be influenced by my beliefs, prior knowledge, training, experiences, and expectations.
10. _____ My creek study will involve a universal step-by-step method that guarantees the generation of valid knowledge.
11. _____ I am interested in pursuing a career in science.

APPENDIX E

SCIENTISTS EXPECTED OUTCOMES AND NATURE OF SCIENCE SURVEY

Appendix E

Scientist Expected Outcomes and NOS Survey

Name:

Occupation:

Date:

Pre-Project Scientist Expected Outcomes and Survey Please complete the following prior to going outside and working with the students. This will provide some insight into best practices for student-scientist partnerships. Thanks for your help!

1. What do you *expect* or hope the students will learn (content, skills, etc.) from this activity? _____

2. What do you think will be the most challenging aspect of meeting these hopes and expectations? _____

3. What do you think will be the easiest aspect of meeting these hopes and expectations? _____

Using the scale below, how would you rank the following statements?

1 = strongly agree 2 = agree 3 = disagree 4 = strongly disagree

1. _____ I can use data from the activity at the creek today for my research or job.
2. _____ High school students have the research skills needed to collect useable scientific data.
3. _____ High school students *think* they have the research skills needed to collect useable scientific data.
4. _____ I have the ability to provide clear instruction to students for the purpose of this activity.
5. _____ All groups today should get similar data about the stream.
6. _____ The students' data will not be influenced by their beliefs, prior knowledge, training, experiences, or expectations.
7. _____ I will show the students a universal step-by-step method that guarantees the generation of valid knowledge for the activity today.
8. _____ This activity will encourage students to pursue careers in science.
9. _____ Research or hands on learning should be a part of high school science instruction.

APPENDIX F

STUDENT POST-TREATMENT SSP FEEDBACK SURVEYS

Appendix F
Student Post-Treatment SSP Feedback Survey

Name:

Date:

Period:

Student Post-Project Survey: Answer the following AFTER going to the creek with Wendy:

1. What was ONE thing you learned from going to the creek today?

2. What was the best part about the creek study today?

3. What was your least favorite part about the creek study today?

Using the scale below, how would you rank the following statements?

1 = strongly agree 2 = agree 3 = disagree 4 = strongly disagree

1. _____ I think my data is important to Wendy and other scientists that may be researching this stream.

2. _____ I had the research skills needed to collect useable scientific data.

3. _____ My classmates had the research skills needed to collect useable scientific data.

4. _____ My data can help solve problems in the real world.

5. _____ I analyzed data to help solve problems in the real world.

6. _____ I completed most tasks with some instruction and guidance.

7. _____ All groups today got similar data about the stream.

8. _____ My data today was collected based on observations.

9. _____ My data collection was not influenced by my beliefs, prior knowledge, training, experiences, or expectations.

10. _____ My creek study involved a universal step-by-step method that guaranteed the generation of valid knowledge.

11. _____ After studying the creek today, I am interested in pursuing a career in science.

APPENDIX G

SCIENTIST POST TREATMENT SSP FEEDBACK QUESTIONNAIRE

Appendix G

Scientist Post-Treatment SSP Feedback Questionnaire

Name:

Job/Position:

Date:

Scientist Post-Project Interview/Expected outcomes: Please reflect on the activity, its effectiveness, and student-scientist partnerships. Thanks for your help today!

1. Would you consider participating in a partnership similar to this again?

2. Would you encourage your colleagues to participate in a study like this?

3. What do you think made the partnership or activity today successful?

4. What aspects of the project/activity did you find most difficult?

5. Did you feel that time was a limiting factor in the success of the partnership? How do you think this could be addressed?

6. Do you think the students met the expected outcomes you outlined in the beginning of the project? If so, which ones?

7. Do you have any suggestions for future student-scientist partnership?

APPENDIX H

BIODIVERSITY INDEX CALCULATION SHEET

Appendix H
Biodiversity Index Calculation Sheet

CODE	ORGANISM	N	Ti	Tv
FL W	Flatworm	<input type="text"/>	6. 0	<input type="text"/>
AQ W	Aquatic Worm	<input type="text"/>	1 0. 0	<input type="text"/>
LEE	Leech	<input type="text"/>	8. 0	<input type="text"/>
SB G	Sowbug	<input type="text"/>	6. 0	<input type="text"/>
SC D	Scud	<input type="text"/>	4. 0	<input type="text"/>
DG F	Dragonfly	<input type="text"/>	4. 5	<input type="text"/>
DM 1	Broadwinged Damselfly	<input type="text"/>	3. 5	<input type="text"/>
DM 2	Narrowwinged Damselfly	<input type="text"/>	5. 5	<input type="text"/>
HLL	Dobsonfly	<input type="text"/>	5. 5	<input type="text"/>
ALF	Alderfly	<input type="text"/>	7. 5	<input type="text"/>
MF 1	Torpedo Mayfly	<input type="text"/>	3. 0	<input type="text"/>
MF 2	Swimming Mayfly	<input type="text"/>	4. 0	<input type="text"/>
MF 3	Clinging Mayfly	<input type="text"/>	3. 5	<input type="text"/>
MF 4	Crawling Mayfly	<input type="text"/>	5. 5	<input type="text"/>
MF 5	Burrowing Mayfly	<input type="text"/>	5. 0	<input type="text"/>
MF 7	Armored Mayfly	<input type="text"/>	3. 0	<input type="text"/>
MF 6	Other Mayfly	<input type="text"/>	3. 0	<input type="text"/>
STF	Stonefly	<input type="text"/>	1. 5	<input type="text"/>
CF1	Hydropsychid Caddisfly	<input type="text"/>	5. 5	<input type="text"/>

Macroinvertebrate Biotic Index Calculator

		<input type="text"/>	<input type="text"/>	<input type="text"/>
CF2	Snail Case Caddisfly	<input type="text"/>	3.0	<input type="text"/>
CF3	Saddle Case Caddisfly	<input type="text"/>	0.0	<input type="text"/>
CF4	Other Caddisfly	<input type="text"/>	3.5	<input type="text"/>
RFB	Riffle Beetle	<input type="text"/>	5.0	<input type="text"/>
WHB	Whirligig Beetle	<input type="text"/>	4.0	<input type="text"/>
WPB	Water Penny Beetle	<input type="text"/>	4.0	<input type="text"/>
CRF	Crane Fly	<input type="text"/>	4.0	<input type="text"/>
BIM	Biting Midge	<input type="text"/>	5.0	<input type="text"/>
BLW	Bloodworm Midge	<input type="text"/>	1.0	<input type="text"/>
MID	Midge	<input type="text"/>	6.0	<input type="text"/>
BLF	Black Fly	<input type="text"/>	6.0	<input type="text"/>
SNF	Snipe Fly	<input type="text"/>	4.0	<input type="text"/>
OTF	Other Fly	<input type="text"/>	1.0	<input type="text"/>
LHS	Left-Handed Snail	<input type="text"/>	9.0	<input type="text"/>
RHS	Right-Handed Snail	<input type="text"/>	7.0	<input type="text"/>
PLS	Planorbid Snail	<input type="text"/>	6.5	<input type="text"/>
LIM	Limpet	<input type="text"/>	7.0	<input type="text"/>
OPS	Operculate Snail	<input type="text"/>	6.0	<input type="text"/>
TOTALS		<input type="text"/>	<input type="text"/>	<input type="text"/>

This tool automates the calculation of the **Macroinvertebrate Biotic Index** as an indicator of water quality. Javascript must be enabled on your browser. Enter number of organisms in the **N** column at left, then click **Calculate**. Click on an aquatic organism for an identification guide. Nonindicator species are shown [here](#).

Tentative Quality Ratings: Revised 2004

ORGANISMS SAMPLED=ΣN =	<input type="text"/>
TAXA RICHNESS = ΣTAXA =	<input type="text"/>
EPT TAXA RICHNESS =	<input type="text"/>

	Taxa Ruchness	EPT Taxa Ruchness	MBI
Excellent	>= 14	>= 5	<= 4.35
Good	12 - 13	4	4.36 - 5.00
Fair	9 - 11	3	5.01 - 5.70
Poor	7 - 8	2	5.71 -

PLEASE VERIFY YOUR DATA SHEETS

CITIZEN SCIENTIST INITIALS _____ DATE _____
 CITIZEN SCIENTIST INITIALS _____ DATE _____

This guide is designed to aid Illinois RiverWatch Citizen Scientists to identify stream macroinvertebrates. Only those stream indicator taxa used in the assessment of stream quality by Illinois RiverWatch are listed in this guide. Not all macroinvertebrates collected can be identified with this guide.

The use of these organisms for stream quality assessment is restricted to the state of Illinois.

Size ranges given are for mature individuals.

Photography: C. Nixon, M. Jeffords, P. Nixon, and M. Rosales Illustrations: C. Nixon and Loren Kirkwood Designed by [Peter Chen](#) for [Illinois RiverWatch](#) Stream Monitoring. Updated: 1/1/2011

APPENDIX I

MICROHYDROASSESSMENT DATA SHEET

Appendix I
Microhydropower Assessment Data Sheet
Determination of Streamflow

Name:

Block:

Date:

Note: The average person uses about 200 gallons of water a day for home use. This does not reflect each person's share of water used for industry (manufacturing things like paper, electronics, etc) or public services.

Predict: This stream can supply enough water to support _____ people daily

Your task: Collect and record data to determine the streamflow measurement. This should tell us if the stream is a viable source of hydropower.

Your group should include the following research positions:

- **Dropper** = drops the ball at the upstream end of the stream reach. Should **communicate clearly** to the timer the "start" time for the ball's float downstream.
- **Catcher** = catches the ball at the downstream end of the stream reach. Should **communicate clearly** to the timer the "stop" time for the balls' float downstream. Should be prepared to get slightly wet.
- **Timer** = using a stopwatch, **measures** and **records** the 3 time trials. Should **listen carefully** to the ball dropper and catcher.
- **Watcher** = follows the ball as it floats downstream to make sure it does not get snagged or caught in back-currents or strainers (debris in river). Should be prepared to get wet!

Work together as a team to complete the following tasks:

Part 1: Stream Velocity Measurement

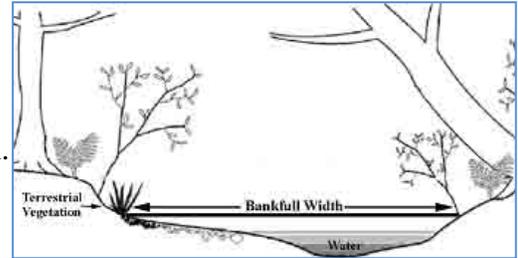
1. Measure and mark a **10 foot distance** along a straight section of stream. This is called a "stream reach."
2. The ball dropper will drop the ball at the upstream end of the reach, and communicate with the Timer to "start the time!"
3. While the ball floats downstream the Ball Watcher will monitor the progress, and move the ball back into the main flow if necessary. Try NOT to interfere with the ball's progress if you can, but if the ball stops completely, you may need to push it out into the current.
4. When the ball reaches the end of the reach, the Ball Catcher will catch the ball and communicate to the Timer to "stop the time!"
5. The Timer will record and share the results with the rest of the group.

DO THIS THREE TIMES and use the AVERAGE TIME for your calculations.

Stream Reach # _____

1st Measurement: 10 ft ÷ _____ sec = _____ ft/sec
 2nd Measurement: 10 ft ÷ _____ sec = _____ ft/sec
 3rd Measurement: 10 ft ÷ _____ sec = _____ ft/sec

→ Average _____ ft/sec

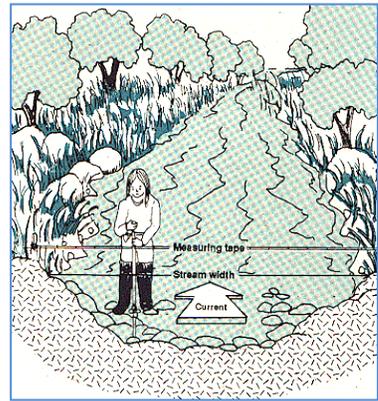


Part II: Stream Width

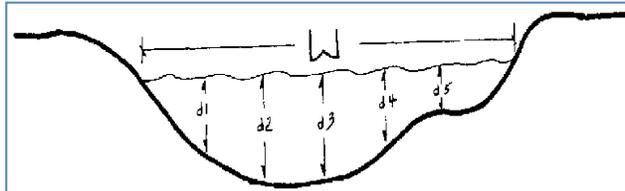
1. Find the average width of the 10 ft reach of the stream.
2. Measure the width of the stream at **three** locations.
3. Divide by 3 to calculate the average stream width.

1st Measurement: _____ Feet
 2nd Measurement: _____ Feet
 3rd Measurement: _____ Feet

→ Average _____ Feet



Part III: Stream Depth



1. Find the average depth of the 10 ft reach of the stream.
2. Measure the depth of the stream in *at least three* places across the stream.
3. Divide the total by 3 to calculate the average depth of the stream reach.

1st Measurement: _____ Feet
 2nd Measurement: _____ Feet
 3rd Measurement: _____ Feet

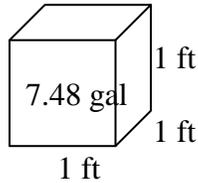
→ Average _____ Feet

Part IV: Calculations

- Find the cubic feet of water flowing per second.
- Multiply** the **ft/sec** (Part I) x average **width**(Part II) x average **depth**(Part III).

$$\begin{array}{ccccccc} \underline{\hspace{2cm}} & \text{ft/sec} & \mathbf{X} & \underline{\hspace{2cm}} & \text{ft} & \mathbf{X} & \underline{\hspace{2cm}} & \text{ft} & = & \underline{\hspace{2cm}} & \text{cfs} \\ \text{(from Part I)} & & & \text{(from Part II)} & & & \text{(from Part III)} & & & \text{Cubic feet of water} & \\ & & & & & & & & & \text{flowing per second} & \end{array}$$

Note: A cubic foot of water is the water in a container 1 foot wide, 1 foot high, and 1 foot long. It contains 7.48 gallons.



In order to determine the number of people who could live from the water in this stream, complete the following calculations.

$$\begin{array}{ccccccc} \underline{\hspace{2cm}} & & \mathbf{X} & \underline{7.48} & & = & \underline{\hspace{2cm}} & \text{gal/sec} \\ \text{Stream flow (cfs)} & & \text{gallons of water/cubic foot} & & & & \text{gallons of water per second} & \end{array}$$

$$\begin{array}{ccccccc} \underline{\hspace{2cm}} & & \mathbf{X} & \underline{60} & & = & \underline{\hspace{2cm}} & \text{gal/min} \\ \text{Gallons of water per sec} & & \text{seconds in a minute} & & & & \text{gallons of water per minute} & \end{array}$$

$$\begin{array}{ccccccc} \underline{\hspace{2cm}} & & \mathbf{X} & \underline{1440} & & = & \underline{\hspace{2cm}} & \text{gal/day} \\ \text{gallons of water per minute} & & \text{number of minutes per day} & & & & \text{total gallons of water} & \\ & & & & & & \text{per day} & \end{array}$$

$$\begin{array}{ccccccc} \underline{\hspace{2cm}} & & \div & \underline{200} & & = & \underline{\hspace{2cm}} & \\ \text{Gallons of water per day} & & \text{gallons of water/cubic ft} & & & & \text{total number of people who} & \\ & & & & & & \text{could live from water in this} & \\ & & & & & & \text{stream in one day} & \end{array}$$

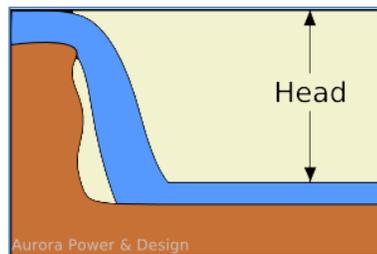
This stream could supply enough water for _____ people per day!

Microhydropower Assessment

To determine if the stream has enough flow to generate power, we will use the calculations from the previous page along with a few other measurements. Below is a simplified version of a microhydro system.

Parts and their functions in a micro-hydropwer system:

- **Diversion:** Collects the water separating out leaves, sticks, sand, mud and other debris.
- **Penstock:** Pipe that carries water from the diversion down to the turbine.
- **Stream:** Flowing water energy resource measured in head and flow rate.
- **Pelton Wheel Turbine:** Device that converts the kinetic energy of the water into rotational motion.
- **Electrical Generator:** Converts the rotational motion into usable electricity.
- **Tail Race:** Chanel to return the power generating water back to the



To calculate the amount of power the stream could produce, you will need to know a few terms:

- **Flow** = the amount of water flowing past over a specific amount of time (cubic feet per second)
 - o In this activity, we will be measuring flow in gallons of water per minute or gal/min.
- **Head** = the vertical drop of the stream over a measured area. This is measured in feet. (see image above)

Stream velocity calculated from previous page: _____ **cfs (ft³/sec)**

$$\frac{\text{ft}^3}{\text{gal/min} \times 1 \text{ second}} \times 7.48 \frac{\text{gallons}}{1 \text{ ft}^3} \times 60 \frac{\text{seconds}}{1 \text{ minute}} =$$

$$\text{Watts of Power} = \frac{\text{Flow} * \text{Head}}{10}$$

(flow)

(head)

(efficiency factor)

$$\text{Watts of Power} = \frac{\text{_____ gal}}{1 \text{ minute}} \times \frac{\text{_____ ft}}{10}$$

$$\text{Watts of Power} = \text{_____ watts}$$

To power a 60 watt light bulb, requires 60 watts. How many light bulbs could this stream power?

Calculate and show your work below.

_____ Light bulbs could be powered by this microhydropower system.

APPENDIX J

ELECTROFISHING POPULATION ASSESSMENT BACKGROUND
INFORMATION



Appendix J Electrofishing Population Assessment Background Information

Aquatic Ecology Lesson:

Hardin Creek Fish Age and Size Class Structure

Dr. Shea Tuberty, Dept of Biology, Appalachian State University

Age or size class structure in [fisheries](#) and [wildlife management](#) is a part of [population assessment](#). Age (in years) can be determined by counting growth rings in [fish scales](#), [otoliths](#) (inner ear bones), cross-sections of fin spines, or teeth for a few species. Each method has its merits and drawbacks. Fish scales are easiest to obtain, but may be unreliable if scales have fallen off of the fish and new ones grown in their places. Otoliths will have stayed with the fish throughout its life history, but obtaining them requires killing the fish. Also, otoliths are difficult to acquire and often require more preparation before ageing can occur.

Analyzing fisheries age classes using size class cohorts

An size class structure with gaps in it, for instance a regular bell curve (see below) for the population of 1-8 year-old fish, excepting a very low population for the 5-year-olds, implies a bad spawning year 5 years ago in that species.

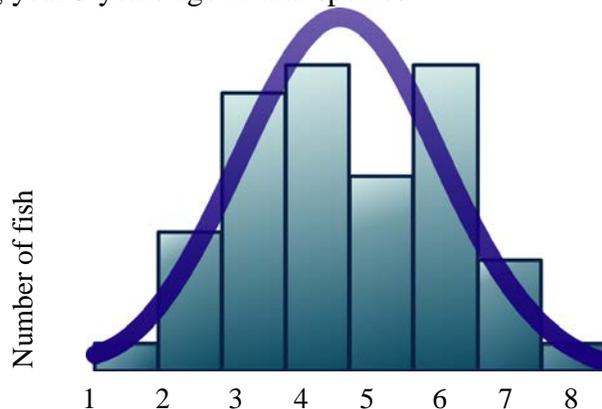


Figure 1. Representation of Size Class Composition of a hypothetical fish population could assume that each size class actually represents a year class of this population. What could possibly occur to cause the small reduction in the 5th size class in the figure above? Often fish in younger age class structures have very low numbers because they were small enough to slip through the sampling nets, and may in fact have a very healthy population. For this reason we will be using a technique called the backpack shocker. Collection methods

Backpack electroshocking delivers a pulse of strong electrical current through the stream water using a rechargeable battery in the shocking unit. The unit has a small computer

that determines the amount of current needed to effectively incapacitate fish based on the water chemistry (conductivity of the water – or its ability to conduct an electrical current). Fish are momentarily caught in the electrical field and this stuns the fish long enough for ecologists (in this case Watauga High School students) to collect the fish.

Population dynamics

A fishery is an area with an associated fish or aquatic population which is harvested for its commercial or recreational value. Fisheries can be wild or farmed. Population dynamics describes the ways in which a given population grows and shrinks over time, as controlled by birth, death, and emigration or immigration. It is the basis for understanding changing fishery patterns and issues such as habitat destruction, predation and optimal harvesting rates. The population dynamics of fisheries is used by fisheries scientists to determine sustainable yields. Without this information populations could be fished to the point of population collapse, and indeed 70% of the worlds fish populations are either fully exploited, in decline, or extinct from overfishing.

The basic accounting relation for population dynamics is the following model.

$$N_1 = N_0 + B - D + I - E$$

where N_1 is the number of individuals at time 1, N_0 is the number of individuals at time 0, B is the number of individuals born, D the number that died, I the number that immigrated, and E the number that emigrated between time 0 and time 1. While immigration and emigration can be present in wild fisheries, they are usually not measured.

A fishery population is affected by three dynamic (constantly changing) rate functions:

- Birth rate or **recruitment**. Recruitment means reaching a certain size or reproductive stage. With fisheries, recruitment usually refers to the age a fish can be caught and counted in nets.
- Growth rate. This measures the growth of individuals in size and length. This is important in fisheries where the population is often measured in terms of biomass.
- Mortality. This includes harvest mortality and natural mortality. Natural mortality includes non-human predation, disease and old age.

Objectives for our study:

- 1) We will conduct a collection of fishes in Hardin Creek using seines and a backpack shocker.
- 2) We will record length and weight data for each fish and determine its species identity
- 3) These data will be plotted in a simple scatter plot graph to determine if there are visible groupings (or cohorts) that will represent size class (and age class) compositions.

- 4) Cohorts will be created based on the data, counted, and that data will be used to make a bar graph to show the size class composition of the populations.
- 5) Students should then attempt to infer some data from these bar graphs. Such as how old fish of each species is likely to live in Hardin Creek, whether there were problems with recruitment during specific years, or if the population is not reproducing well.
- 6) A short paragraph describing the findings should be prepared along with the graphs generated for each species.

APPENDIX K

ELECTROFISHING STUDENT READING

Appendix K

Electrofishing Student Reading

Name:

Date:

Period:

Electrofishing Reading Read the article on electrofishing and answer the following questions.

1. Using your own words, define electrofishing.

2. What do fisheries managers use electrofishing to do?

3. Using internet resources describe the three details (from answer #2) fisheries managers use electrofishing to learn about fish populations.
 - a.
 - b.
 - c.

4. What are the two ways biologists can electrofish? _____ and _____

5. What happens to a fish when it swims reaches an anode?

6. What is narcosis? _____

7. About how long will narcosis last? What does this mean for biologists trying to catch the fish?

8. What kinds of information will scientists gather as they “process the fish?”

9. What do you hope to learn from Dr. T while we electrofish on Monday?

10. Do you think the information we use will be helpful to his research? Why or why not?

Russian River Coho Recovery Project Read the article on Coho Salmon and answer the following questions.

1. Where is the Coho River? _____
2. What species of fish live in the Coho River? _____
3. Using the internet as a resource, what is a fingerling?
4. Why is it encouraging that the juvenile fish survive into the fall?
5. Using the internet as a resource, what does it mean when a fish spawns? What kinds of fish spawn? Do fish that live in NC spawn – if so, which ones?

For each section heading in the article, write a ONE SENTENCE summary about the section.

Hatchery Rearing Challenges

Genetic “matrix” Developed

Landowners Learn Stewardship

Monitoring Enhances Success

Agency Collaboration Critical

6. How can the recovery on this river relate to recovery projects in North Carolina?

APPENDIX L

SCIENTIST SCAVENGER HUNT

Appendix L
Scientist Scavenger Hunt

Name: _____ Date: _____ Period: _____

Scavenger Hunt: Who is Dr. T?

Introduction: You have the opportunity to help Dr. T conduct research on the New River. Before you can help him, you must first be familiar with what he studies. Dr. T is a professor at Appalachian State University in Boone, NC, and has agreed to take you guys on a research adventure! Using his website (link is posted below), answer the following questions about his research!

<http://www1.appstate.edu/~tubertysr/>

Part 1: Who is Dr. T?

1. What are Dr. T's research interests?

2. What type of invertebrates does he mostly study?

3. What is of particular interest to Dr. T?

4. How could the study of crustaceans and other macroinvertebrates (the critters we studied with earlier in the semester) give us information about fish? How could studying fish populations give us information about crustaceans and macroinvertebrates?

Use the link below to find out about Dr. T's current research projects:

http://www1.appstate.edu/~tubertysr/grad_student_projects.htm

1. What happened on the New River to lead Dr. T and his graduate students to study the macroinvertebrates (MI)?

2. What two things are they trying to figure out through this project?

3. Using the internet and this page, describe the chytrid fungus. Why is studying the chytrid fungus important to amphibian populations?

APPENDIX M

FISH POPULATION STUDY ANALYSIS

Appendix M

Fish Population Study Analysis

Hardin Creek Fish Population Study: Data Analysis Instructions for Open Office Calc
By the end of the activity you should have constructed the following in Open Office Calc:

- ✓ Scatter plot of age and length for each species
- ✓ Age group data table for each species
- ✓ Age group population bar graph for each species
- ✓ Answered analysis questions 1-6 on a separate sheet of paper.

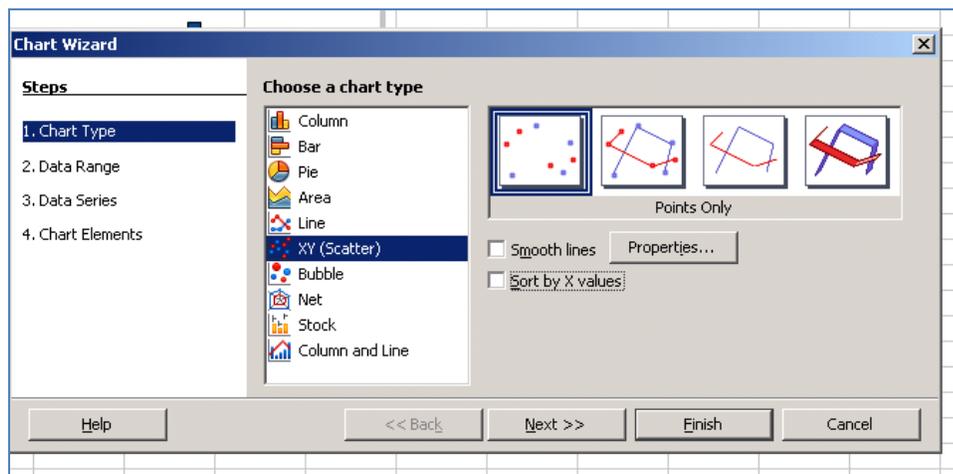
Part 1: Making the Scatter Plot Graph

Before we can assess the age distribution, we will need to classify out fish into cohorts or age groups. We will do this by creating a scatter plot graph of the length and weight for each species.

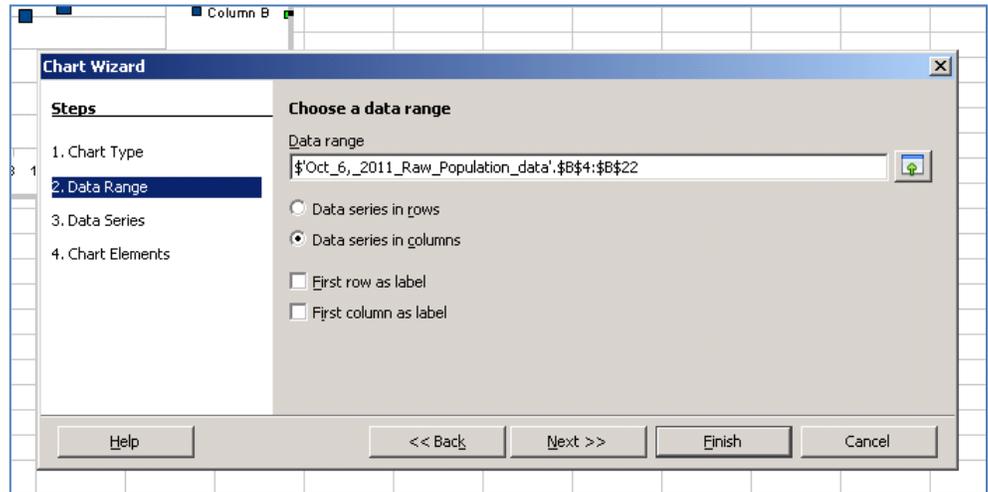
1. Open the data set from the fusion webpage. Folders → Unit 04: Water and Streams → File Name: Copy of Hardin Creek Fish Size Class Experiment.
2. Save a copy of the file so you can edit it. You will probably want to save it to My Documents, so that you can access the file when you are away from school.
3. You will be creating a graph for *each* species collected in Hardin Creek. For this reason, the fish have been categorized by species. Be sure to include species name (common and scientific) in your graph.

To make the graph:

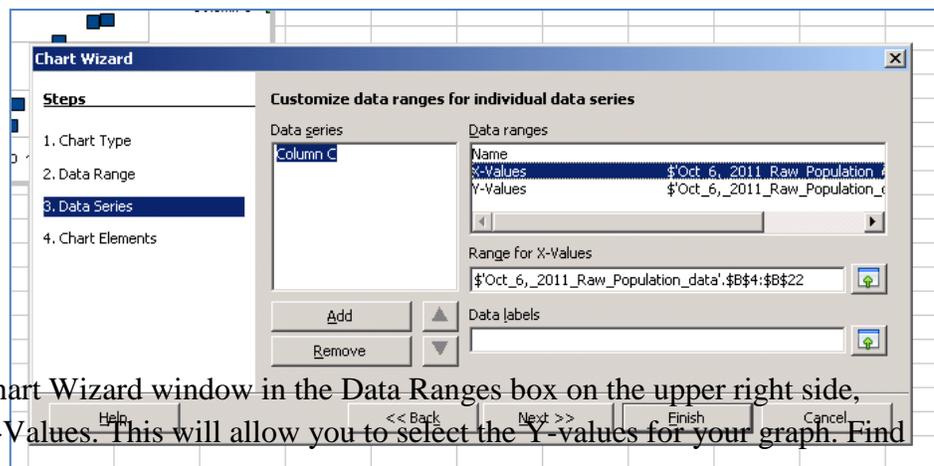
4. Decide which species of fish you will graph first.
5. Go to INSERT → CHART
6. In the Chart Wizard window, select **XY (Scatter)**. Click Next. Do not select any variations that have a trend line at this time.



7. Next you will select your data range. This will be the values for the WEIGHT of the fish. To select these values, you will need to click on the small box to the right of the text box in the chart wizard window. This will allow you to go out into the spreadsheet and select the values you want to include. Be sure to select ONLY the values – not the headings. We will add titles and labels later. When you have selected the values in the spreadsheet, you can click the small box again and it will take you back to the chart wizard window.
8. Select “Data series in columns”
9. Deselect the boxes that say “First row as label” and “First column as label.” Click NEXT.

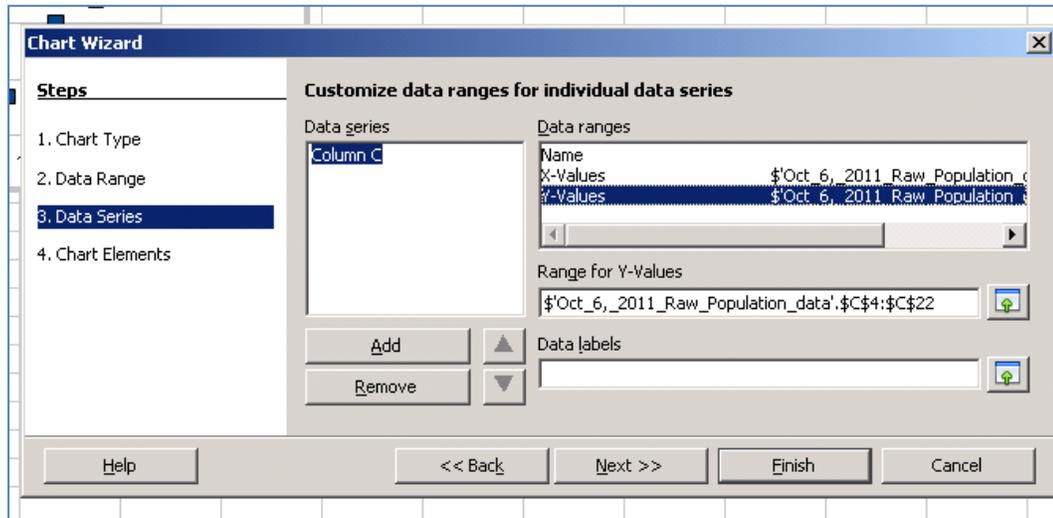


10. In the Data Series Chart Wizard window, you will select the values to use for the x axis and y axis of your graph. In the window find the box labeled Data Ranges on the right side. Click on X-values. Find the box below labeled Range for X-Values. Click on the small box to the right of the Range for X-Values box. This will allow you to go out into the spreadsheet to select your values. Click this box again to get back to the Chart Wizard Window.



11. In the Chart Wizard window in the Data Ranges box on the upper right side, select Y-Values. This will allow you to select the Y-values for your graph. Find

the box labeled Range for Y-values. Click the small box to the right of the Range for Y-values box. This will allow you to go out into the spreadsheet to select your values. Click this small box again to return to the Chart Wizard window. Click NEXT.



12. In the Chart Wizard window you will now label your X-axis, label your Y-axis, and give your chart a title. Make sure to include UNITS in your labels. Click FINISH.

Repeat these steps for *each* species collected. When you have an X,Y Scatter Plot for each species show this to your instructor.

Part 2: Identifying age groups using a scatter plot graph

Now that you have scatter plots for *each* species, you will need to assign fish into age groups or cohorts based on length and weight.

1. Identify the parameters to classify each age group. A good suggestion is to use 0-50 grams as age group 1, 50-100 as age group 2, and so on. This classification will be different for EACH fish species, so you will have to make different parameters for each species.
2. Once you classified your age groups, count the number of species in each age group. Create a small data table that includes the species name, age group identifier (0-50 grams) and the number of fish that fall into this category. Be sure to assign a group number. You will need this for your graph later. You should have a data table for each species. Below is an example.

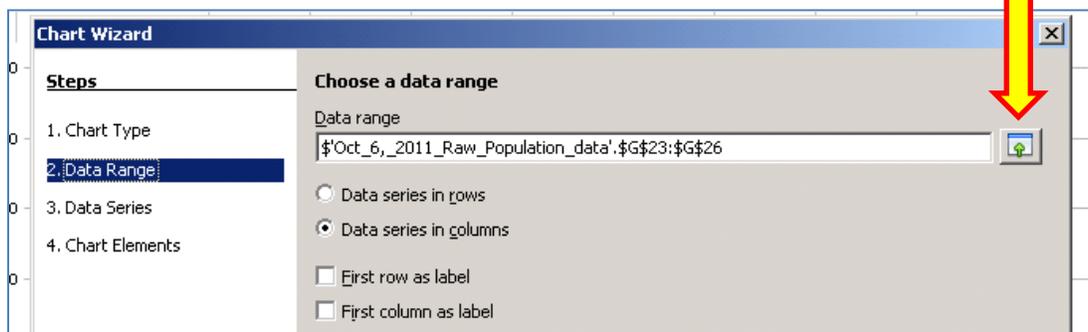
Fish Species: Brown Trout (<i>Salmo trutta</i>)		
Age Group	Description	Number of Fish
1	(0-15 grams)	27
2	(16-30 grams)	15
3	(31-60 grams)	7

When you have charts for age groups for all species, show this to your instructor to check before proceeding.

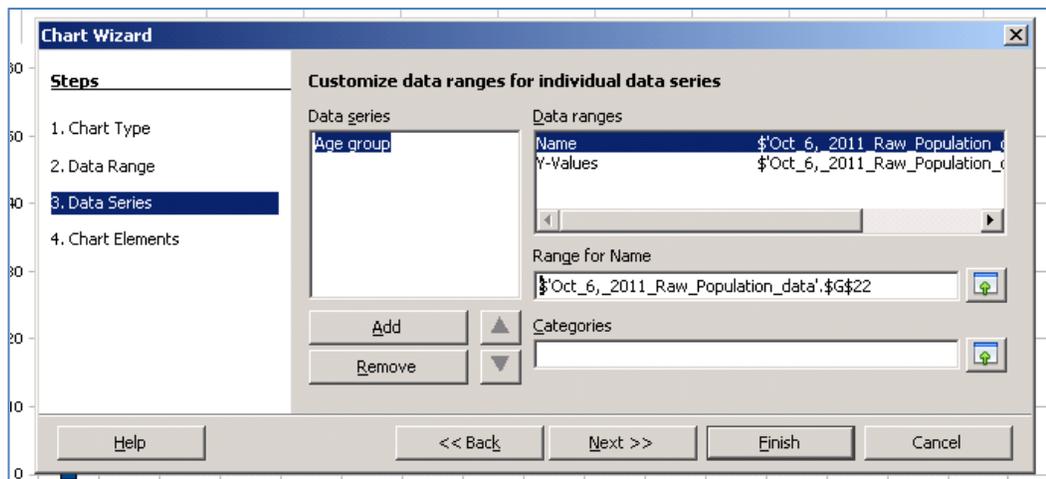
Part 3: Age Structure Graphs

Now that you have your age structure groups, you can create a bar graph to show the distribution of each age group. This will help us determine the health of the fish population in the stream.

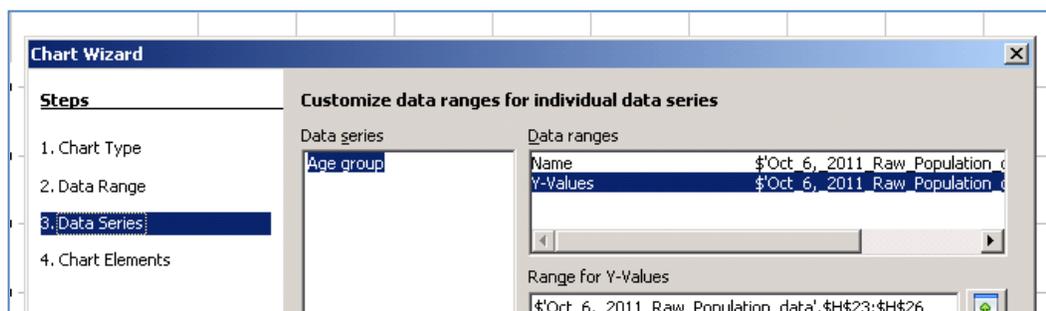
1. Decide which species of fish you will graph first.
2. Go to INSERT → CHART
3. Select a column chart. Click NEXT.
4. Next you will select your data range. This will be the values for the AGE GROUPS of the fish. To select these values, you will need to click on the small box to the right of the text box in the chart wizard window. This will allow you to go out into the spreadsheet and select the values you want to include. Be sure to select ONLY the values – not the headings. We will add titles and labels later. When you have selected the values in the spreadsheet, you can click the small box again and it will take you back to the chart wizard window.
5. Select “Data series in columns”
6. Deselect the boxes that say “First row as label” and “First column as label.” Click NEXT.



- In the Data Series Chart Wizard window, you will select the values to use for the x axis and y axis of your graph. In the window find the box labeled Data Ranges on the right side. Click NAME. Find the box below labeled Range for Name. Click on the small box to the right of the Range for Name box. This will allow you to go out into the spreadsheet to select the cell that describes the Age Group. This will be a text cell; no values will be selected here. Click the small box again to get back to the Chart Wizard Window



- In the Chart Wizard Data Series window select the Y-Values tab in the Data Ranges box in the upper right hand corner.
- Find the box labeled Range for Y-values. Click the small box to the right of the Range for Y-values box. This will allow you to go out into the spreadsheet to select your values. Click this small box again to return to the Chart Wizard window. Click NEXT.



10. In the chart elements window you will label your x-axis and y-axis and give your chart a title. Be sure to included units where necessary.

When you have created an age structure graph for ALL species, show this to your instructor.

Part 4: Analysis Questions

Answer the following on a separate sheet of paper.

1. Which fish species had the largest population based on your data?
2. Which fish species had the smallest population based on your data?
3. What was the largest size fish collected?
4. What was the smallest size fish collected?
5. Do you have an even age distribution graph for each species? Create a list of species that had normal distribution.
6. Did you have any fish populations with an abnormal age distribution? For each abnormal distribution that you found, describe the abnormality. Use these guidelines for your answer:
 - a. Where there more young fish? Were there more old fish?
 - b. Was one age group significantly larger or smaller than another age group?
 - c. What could this mean for the species population in Hardin Creek?
 - d. What might have caused differences among age groups?
 - e. Predict what you think this could mean for the future of the population of this species.

