AN EXAMINATION OF WHETHER ENGAGING IN AUTHENTIC SCIENCE HAS AN IMPACT ON HIGH SCHOOL STUDENTS' AGENCY TO ACHIEVE ECOJUSTICE IN THEIR LOCAL COMMUNITY

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Billie Jeanette Long
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DEDICATION

Thank you to my children, Hannah and Levi. You continually inspire me strive to be a better person. I will always remember the joy of walking near and playing in the creek with you.

Thank you to the hundreds of students I have had the opportunity to work with. It has been a joy watching you wade in the stream in waders boots for the first time, hold a mayfly in your hand, kiss a northern hogsucker, refuse to leave a stream clean up until you retrieved that buried tire or shopping cart, become the expert on your research topic, and love our stream.

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ABSTRACT

An ethnographic case study was completed examining the possible impact of engaging in environmental field research, an authentic science experience, on high school students' agency to achieve ecojustice in their local community. The researcher worked with fourteen students, as a teacher and participant observer, for four months.

The two frameworks that guided the design, implementation and analysis of this inquiry were agency and ecojustice. Data was gathered in the form of observations, interviews, and analysis of documents. Three major themes with subthemes were identified including Understanding of Local Environmental Problems – Causes, Impacts, Solutions; Changing Roles – Gaining Knowledge/Power, Becoming Researchers, Influencing Others; and Impact of Peer Review. The results show that student researchers, developed the following over the course of the study: 1) greater awareness of local environmental problems, their causes and impacts; 2) more sophisticated understanding of potential solutions to the problems and means by which stakeholders could participate in achieving these solutions; and, 3) increased agency to address local environmental problems by way of discourse and other actions including feeling empowered to share information with the local community, with policy makers, and with the scientific community. While student agency increased over the course of the study, students continued to feel limited in their ability to impact their local community. Students whose research focused on environmental field studies of local aquatic ecosystems versus other topics related to aquatic biology exhibited a more pronounced increase in agency. They began to see themselves as someone with knowledge and power who could bring about positive change.

Recommendations for practitioners based on the findings of this work include the need to provide opportunities for students to engage in environmental field research in their local communities. This experience should allow students to choose their own research topic, design their study, and engage in peer review. Recommendations for additional research on this topic include the need for an examination of the impact of explicit ecojustice education. In addition, it would be beneficial to determine the impact of student engagement in environmental field research over a more prolonged time frame.

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CHAPTER ONE
INTRODUCTION AND GENERAL INFORMATION

Problem Statement

Science educators are amid an exciting and challenging paradigm shift. Previously, science practices have been taught in an isolated fashion or, at best, embedded in science content. The *Next Generation Science Standards* (NGSS Lead States, 2013) which were developed based on *A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas* (NRC, 2012), shifts the focus to three dimensions: 1. Scientific and Engineering Practices; 2. Crosscutting Concepts; and 3. Disciplinary Core Ideas. Science content (disciplinary core ideas) is best taught embedded in science practices with connections being made by way of crosscutting concepts. This paradigm shift is an adjustment for both educators and students. Collins (1997) described three barriers toward effective implementation of the 1996 National Science Education Standards as lack of vision, and limitations about materials and time. Arguably, these same three barriers exist in relation to the effective implementation of standards based on the Framework for K-12 Science Education. Ultimately, this evolution of K-12 science standards is leading towards an increase in authentic science learning opportunities for students.

Science educators are tasked with creating impactful learning opportunities for students that allow them to gain an understanding of both

science content and science practices (National Research Council, 2012; NGSS Lead States, 2013). Creating opportunities for students to engage in authentic science experiences has been found to be an effective means for students to learn to engage in experimentation (Aydeniz, Baksa, and Skinner, 2011) and learn science content (Houseal, Abd-El-Khalick, and Destefano, 2014; Sadler, Burgin, McKinney, Ponjuan, 2010; Shein and Tsai, 2016; Ward et al, 2016). Participation in authentic science learning opportunities can help students gain an understanding of the Nature of Science (NOS) (Houseal et al., 2014; Sadler et al., 2010; Shein and Tsai, 2016; Ward et al., 2016). In addition to authentic science learning experiences, students benefit from explicit NOS instruction (Aydeniz et al., 2011).

Environmental science provides opportunities to engage students in authentic science experiences in their local communities. A recognition of the need for an environmentally literate citizenry has resulted in a push to incorporate environmental education in the K-12 school curriculum (NAAEE, 2013). Environmental education should include an examination of issues pertaining to ecojustice including “unequal distribution of harmful environments between people,” and “justice towards nature.” (McLaren and Houston, 2004). Place-based education can be an important component of ecojustice pedagogy (Karrow and Fazio, 2010). Fostering student connections to their local environment can promote a caring attitude toward that environment which, can, in turn, result in a desire to act. Participation in environmental field research in

their local communities can result in students becoming activists (exerting agency) to achieve ecojustice in those communities (Ceaser, 2012; Dimick, 2012).

This study examined whether high school students' participation in authentic science impacted their agency to achieve ecojustice in their local natural environment. A qualitative ethnographic case study methodology was employed with a group of students who designed, conducted, and communicated original environmental field research. The theoretical framework that guided this research is critical theory (Guba and Lincoln, 1994; Leonardo, 2001) and critical science agency (Calabrese Barton and Tan, 2010).

Purpose of the Study

The purpose of this study is to examine whether participation in authentic science (designing and conducting original environmental field research) impacts students' agency to achieve ecojustice in their community. Areas explored in this study include the following:

- How do students view issues of ecojustice in their local environment?
- What power do students feel they have to take action to achieve ecojustice in their local environment?
- What motivates students to take action to achieve ecojustice in their local natural environment?
- What barriers exist that inhibit students from acting to achieve ecojustice in their local natural environment?

Need for the Study

Researchers have examined various science learning opportunities with regard to how closely they achieve authentic science and how engaging in these learning opportunities impacts students (Table 1). General findings from these studies indicate participation in authentic science can increase content knowledge (Houseal et al., 2014; Ward et al., 2016), experimentation skills (Aydeniz et al., 2011), interest in science (Sadler et al., 2010; Shein and Tsai, 2016), and understanding of Nature of Science (NOS) (Sadler et al., 2010; Burgin, McConnell, and Flowers, 2015).

For authentic science experiences to be effective, students need input regarding developing a research question as well as selecting appropriate materials and methods (Waight and Abd-El-Khalick, 2011). As part of this study students developed an original research question and determined what materials and methods to utilize. They engaged in peer review and shared their findings in the form of a paper and a presentation which they shared beyond the classroom, thereby contributing to the body of knowledge on their research topic.

Researchers examined how participation in environmental projects impacts students' agency (Ceaser, 2012; Dimick, 2012). However, this research did not involve students' designing and conducting their own research such that they produced a product (scientific paper and presentation) contributing to the body of knowledge. Students in my study designed and conducted original research. They worked as a team of scientists and engaged in the peer review

process. They produced a scientific paper and presentation and shared findings with the local community and with the scientific community. In this way students were situated as creators of knowledge and agents of change in their local communities.

Limitations

The focus of my study is limited to high school students who attend a public school in the Southeastern United States. These were students who chose to register for, and who had the prerequisites to register for, an Aquatic Biology (Scientific Research) Honors class. The prerequisites for these courses include Biology I and Chemistry I. These prerequisites limit the grade levels of these students to junior and senior years. While this course does count as one of the four required science courses for these students, there are several other science course options for junior and senior students (Advanced Placement Biology, Advanced Placement Chemistry, Advanced Placement Environmental Science, Advanced Placement Physics, Environmental Science, Physics I, Chemistry II Honors, Biology II). The length of the study was dictated by the time the students were in the course. The school operates on a block schedule. Each semester is 90 school days. Participation in the study was voluntary and fourteen of the eighteen students in the class chose to participate. Participating students were asked to attend three individual interviews which were scheduled before or after school. One student was unable to attend any of the interviews.

One student could only attend one interview. These limitations mean the participants are not reflective of the entire student body of this school or of high school students in general.

Delimitations

The school that serves as the study site was chosen because I teach at this school. The class selected for the study was a class taught by me. The study is limited to one course because the curriculum of this course allows for students to complete environmental field research.

Assumptions

I have extensive experience completing environmental field research, teaching environmental science, and mentoring students in completing environmental field research. I have an MS in Environmental Science, have presented research at scientific conferences and have published research in an environmental science journal. I have taught science courses at the high school and community college level for twenty years. During these twenty years, I have designed learning opportunities that allow students to participate in original environmental field research. Throughout this time, students I have mentored have presented their research at science symposia for high school students. Some of these students have had their research published. I am also an environmental activist who sponsors an environmental club which engages high

school students in environmental service learning and outreach to younger students (elementary students and scouts).

This experience is an asset to the study in that I have a proven track record in mentoring students in the completion of environmental field research. However, this experience also means that I have established ideas regarding the impact engaging in such research has on high school student's agency to achieve ecojustice in their community. It was important for me to be cognizant of my preconceived ideas regarding this topic and I was diligent in my attempts to set these ideas aside as I gathered and examined data.

Definitions of Terms

Agency is defined in the researched proposed here as the ability to recognize one's power and take action. As students interact with their local environment and gain confidence in their ability to engage in the field research process, it was predicted they would feel empowered to act to cause positive change.

Ecojustice is defined as justice for the natural environment, including humans who are part of the natural environment. Use of the term implies recognition that inequities exist in how groups of people benefit from use of environmental resources and how groups of people are harmed by environmental degradation. Further, use of the term implies recognition of nature

as having intrinsic value and recognition of the negative impact of anthropogenic activities on the natural world.

Environmental field research is defined as research completed in a field setting in which one or more aspects of the natural environment are studied.

Local natural environment is defined as follows. The local environment is the location where students routinely spend time including where they live, go to school, work, and play. The natural environment is defined as naturally occurring elements (biotic and abiotic) in an area. This is not meant to imply a pristine environment untouched by humans. Natural and human-created environments are intertwined.

Theoretical Framework

Two frameworks guided the design, implementation and analysis of this inquiry, agency and ecojustice, with critical theory being the guiding theoretical framework. The purpose of critical theory is to transform structures that are oppressive (Guba and Lincoln, 1994). Critical theory has a "goal of advancing the emancipatory function of knowledge." (Leonardo, 2004).

Critical Theory

Critical theory is a social theory with a focus on analyzing the underlying assumptions of social structures. While critical theory is important for social science, it is also valuable in an analysis of the positivist tradition associated with science (Agger, 1991). Traditionally, science has been viewed as a task that is

objective and value-free. It has a history of engagement in experimental methods that lead to as close an understanding of a reality that exist as possible. In fact, in science, as is the case of social science, inquiry is value-laden. Values of the researcher and others involved in the research shape findings. Researchers, in any field, can be activists and findings can serve as catalysts for change.

In education settings, teachers are often the ones with power and they are transmitting information (content knowledge generated by scientists) to students who are not in a position of power and do not have standing to construct knowledge. Leonard (2004) states the quality of education "is proportional to the depth of analysis that students have at their disposal." He goes on to explain the act of criticism reflects engagement and that another component of this quality education is an assumption that transcendence or change can occur. Experiencing this type of education can be empowering for students. Critical theory helped me in my study because the research I conducted focused on empowering student to take action in their local environment to bring about ecojustice.

While some accounts of critical theory position the researcher in a more authoritarian role as one who has knowledge of existing inequities and is in a role to reveal them to participants (Guba and Lincoln, 1994), my research does not hold with that tradition. My research does begin with an understanding that inequities exist. However, in my research the nature and extent of these

inequities and the course of action to take with regard to resolving them was determined by all involved (researcher as participant and other participants). Through their research, students asked questions regarding their local environment, conducted research, and shared their findings.

Agency

Agency as defined by Emierbayer and Mische (1998) is “the temporally constructed engagement by actors of different structural environments – the temporal – relational contexts of action – which, through the interplay of habit, imagination, and judgement, both reproduces and transforms those structures in interactive response to the problems posed by changing historical situation.” (p. 970). They describe three components of agency: 1. iteration, 2. projectivity, 3. practical evaluation. Iteration involves past patterns of practice and their impact on current action. In this way, routine habits are evidence of agency. Choices that are made are impacted by past experiences. Projectivity involves looking toward the future and imagining possible actions. Experimental enactment is one part of projectivity described by these authors. This is a time when individuals try on different ways of behaving and see themselves in various roles. This can by particularly important for teenagers. And, practical evaluation involves making decisions among several choices of action. Information is considered and options are weighted, a decision is made, and a plan of action is executed. The question is not whether participation in a specific set of learning opportunities

causes one to have agency, but rather does participation in a specific set of learning opportunities impact agentic orientation? The concept of agency is a critical component of my research because I wanted to examine if engaging in authentic science impacts students' agentic orientation such that they feel empowered to take action (weigh options, make decisions, and take action) to address ecojustice issues in their local community.

Critical science agency is established when students develop rich understanding of science content and practices such that they recognize themselves as an expert regarding a particular topic. (Calabrese Barton and Tan, 2008). Students' view of themselves as an expert and as someone who can do science, influences their view of their ability to take action in their area of expertise (Basu, Barton, Clairmont, Locke, 2009; Calabrese Barton and Tan, 2010). The authentic science experiences students were provided in my study were designed to help them establish critical science agency by allowing them to become the expert on their topic of study. They asked the questions, designed the study, conducted the study, and shared their findings. In my research, I followed students on their journey to expertise by being a participant observer as they progressed through the research process.

CHAPTER TWO
LITERATURE REVIEW

My literature review begins with an overview of research on secondary students' experiences in authentic science learning opportunities. Reviewed research focuses on how engaging in these learning opportunities impacts students' understanding of science content, ability to engage in the practice of science, interest in science, and understanding of the Nature of Science (NOS). Next, I examine research on agency and how learning opportunities can empower students to exert agency through discourse and action. Finally, I examine research on ecojustice. Here I review studies that focus on how engaging in environmental studies can empower students to exert agency to achieve ecojustice in their local communities. This literature review provides the foundation for my research which combines the topics of authentic science, agency, and ecojustice in a manner that has not previously been examined in depth. I am interested in following students as they travel on a journey toward expertise on an environmental issue in their community by way of original scientific research and examining if that journey towards expertise impacts their likelihood to exert agency through discourse and/or action to achieve ecojustice in their community.

Review of Literature Related to Authentic Science Experiences for Secondary School Students

Research focused on impacts of students' experience with authentic science fall into four major categories (Table 1). Category One involves inquiry classroom activities. Category Two involves student-teacher-scientist partnerships (STSPs). Category Two experiences can occur at the school setting or at a field location. Category Three involves student apprenticeships. These experiences usually occur at a university. Category Four involves museum-based experiences.

Table 2.1. Major studies on authentic science learning opportunities for secondary students.

Study	**Project Type**
Chinn and Malhorta (2002)	Inquiry Classroom Activities
Sadler et al. (2010)	Student Apprenticeships
Aydeniz et al. (2011)	Student Apprenticeships
Waight and Abd-El-Khalick (2011)	Inquiry Classroom Activities
Houseal et al. (2014)	Student-Teacher-Scientist Partnerships
Burgin et al. (2015)	Student Apprenticeships
Shein and Tsai (2015)	Student-Teacher-Scientist Partnerships
Achiam et al. (2016)	Museum-Based Experience
Burgin and Sadler (2016)	Student Apprenticeships
Chapman and Feldman (2016)	Student-Teacher-Scientist Partnership
Ward et al. (2016)	Student-Teacher-Scientist Partnership

Category One: Inquiry Classroom Activities

The release of the National Science Education Standards in 1996, resulted in an increased focus on incorporating inquiry activities into the science classroom (NRC, 19916). Chinn and Malhorta (2002, p. 177) citing others, state "Authentic scientific inquiry refers to the research that scientists actually carry out. Authentic scientific inquiry is a complex activity, employing expensive equipment, elaborate procedures and theories, highly specialized expertise, and advanced techniques for data analysis and modeling (Dunbar, 1995; Galison, 1997; Giere, 1988). Schools lack the time and resources to reproduce such research tasks. Instead, educators must necessarily develop simpler tasks that can be carried out within the limitations of space, time, money, and expertise that exists in the classroom." (Chinn and Malhorta, 2002, p. 177). Several researches have focused on inquiry in the classroom, how closely inquiry resembles authentic science, and how engaging in authentic science experiences impacts student understanding of science.

Three types of simple inquiry tasks that would typically occur in the classroom include simple experiments, simple observations, and simple illustrations (Chinn and Malhorta, 2002). Each type is designed to help students learn about terms, skills, concepts, or phenomenon. A comparison of these three typical types of science activities performed in classrooms, revealed that none of these activities approximates authentic science. A major piece of authentic science that was lacking was input/decision making by the student (from

research question, to research design, to tool choice). While these activities do involve examining a question, carrying out a procedure and using tools, which are all parts of authentic science, students do not have input. In addition to these shortcomings, many pieces of authentic science are not present in any form. For example, scientists routinely self-reflect and identify flaws in their own work. Rarely, do students engage in this type of self-reflection. Considering, students have no input into the process, even when they are asked to discuss study limitations, they can generally only explain if they feel they made an error in conducting the experiment. Another cognitive function present in authentic science is the importance of comparing multiple studies. Students rarely read primary literature or even engage in the peer review process which would allow them to read the work of classmates. While students do work with data; such work is generally limited to the creation of simple data tables or graphs (Chinn and Malhorta, 2002). Failing to incorporate these types of activities routinely performed by scientists results in a limited science experience for students.

Perhaps more important than the limitations regarding cognitive function are the epistemological discrepancies between authentic science and simple classroom inquiry tasks (Chinn and Malhorta, 2002). Engaging in typical school inquiry may not only fail to support student understanding of authentic science but may hinder student understanding of the nature of Science because of a disconnect in epistemologies (Chinn and Malhorta, 2002). Not only are the inquiry tasks in which students engage significantly different than those in which

scientists engage, the reasoning required for each type of tasks is significantly different. For example, scientists engage in argumentation regarding existing theories. Students generally gather data in a pre-determined fashion in an attempt to arrive at the “correct” answer. They generally do not engage in argumentation or recognize the theory-laden and tentative nature of science.

At about the same time as the release of the National Science Education Standards (1996), the Biology Workbench was created, initially for use by scientists to analyze amino acid sequences and identify proteins. A version of the Biology Workbench was subsequently created to provide high school students with an authentic science experience. Teachers received training to utilize this program in their classrooms. For the most part, this program and the teacher training were seen as unsuccessful because few teachers continued to use the program in their classroom for a sustained period (Waight and Abd-El_Khalick, 2011). Student use of this scientific technological tool did not provide an authentic experience because class activities tended to be teacher-led and the students were passive learners for the most part. The students seemed primarily focused on using the program correctly and attempting to get the correct answers. For instance, student-teacher interactions often consisted of the teacher telling the student how to advance through the online program. Students expressed reticence to try something different for fear they would make a mistake that would be difficult to correct in the program.

Category Two: Student-Teacher-Scientist Partnerships

Other attempts at providing authentic science learning experiences for students involve partnering with scientists and engineers. These partnerships might occur in the classroom, at a laboratory or university, or at a field location.

A Student-Teacher-Scientist Partnership (STSP) called Students, Teachers, Rangers, and Research Scientists (STaRRS) was examined by Houseal et al. (2014) with the goal of assessing how participation impacted students' content knowledge and attitudes toward science and scientists. The study was quasi-experimental with the intervention group consisting of 193 students and 9 teachers and the control group consisting of 187 students and 11 teachers. Pre- and post- tests were given to assess content knowledge and attitude toward science and scientists. This project required extensive commitment from teachers in the intervention group who participated in an initial week-long professional development program at Yellowstone National Park prior to the beginning of the school year. Teachers then worked with their students throughout the school year, with support from project personnel. Tasks during the school year focused on becoming familiar with content, skills, and tool use. Students could develop some research questions prior to the expedition. These teachers and their students then completed a field expedition project to the Yellowstone National Park where they worked directly with rangers and research scientists. Subsequently, students gave presentations of their work at school events and science fairs. Intervention group teachers then attended a follow-up

session at Yellowstone National Park with rangers and research scientists. The control group of students and teachers only participated in an expedition at Yellowstone National Park. A major finding of this study was that content knowledge of intervention group students increased significantly more than content knowledge of control group students. Regarding attitude toward science, there were two major findings. STaRRs students had a higher rating on seeing scientists as regular people than the control group students. Both the STaRRs students and the control group students had a more negative attitude toward engaging in science activities in their free time; although the STaRRs students exhibited less of a decline in this area.

A Scientists Teacher Collaborative Model (STCM) was utilized in a public high school High Scope Environmental (HSE) course in Taiwan (Shein and Tsai, 2015). Students in this eighteen-week long course were freshman. The control group in this mixed methods study experienced a traditional teacher-led learning environment. For the intervention group, teachers met with scientists to design the course. Throughout the eighteen weeks, scientists came into the classroom to lead lecture and lab experiences. Students were given a pre- and post-test to measure scientific competency and interest. Student competency was measured using items from the PISA 2006 science assessment. Researchers found that participation in the intervention group led to what they describe as a medium positive effect on student competency and a large positive impact on student interest in science.

Research assessing how engaging in a scientific study focused on algae as a potential biofuel impacted twelve high school students in a Marine Science Honors course was completed by Chapman and Feldman (2016). Two questions of these researchers were whether the students perceived the project as authentic science and how participation impacted their view of scientists and view of themselves as scientists. This study utilized mixed methods. Data included pre- and post-surveys, post interviews, classroom observations, student journals, student presentations, pre- and post-skills survey and pre- and post-Identify-a-Scientist (IAS) assessment. Students and their teacher worked with a university environmental engineering professor and her graduate student. The professor shared details of her research focused on the potential of alga as a biofuel. Students built a bioreactor on their high school campus. Initially, they followed prescribed protocols to obtain data. In a second phase of the project, they had the opportunity to develop their own research questions and protocols based on the topic. Students could engage in discussions with the professor and her graduate student. As part of the experience, they did attend presentations in which university students presented original research. These high school students also presented their research to peers, teachers, the supervising university professor, and others. Findings of this research include the following. Students did perceive the experience as authentic science. After the experience, students had moderate to strong science identity (as measured according to Carlone and Johnson, 2007). Students' views of who can do science generally

broadened as a result of participating in the project. However, Hispanic male students continued to have narrower views of who could do science as reflected by the fact that the likelihood of them choosing a Hispanic scientist on the IAS instrument decreased.

The *Air Toxics Under the Big Sky* program provides students a research topic, namely air quality, but allows them to develop a specific research question pertaining to the topic and design and conduct original scientific research based on this question (Ward et al., 2016). This project is completed in collaboration with a researcher from the University of Montana. The researcher comes to the classroom to provide information about air quality to students and remains accessible to teachers and students throughout the year as needed. Students then complete modules focused on content and skills such as equipment use. Participating schools are provided with necessary equipment. Next students develop their own research questions and plans and conduct original scientific research. Ultimately, students analyze their data and create posters and presentations. Their work is presented at an annual symposium at the University of Montana. At the symposium, students are questioned by a panel of scientists and expected to justify their conclusions. The treatment group in this study consisted of nine classes from five schools participating in the *Air Toxics Under the Big Sky* program. The control group consisted of classes using traditional teaching methods. A total of 180 control group and 199 treatment group juniors and seniors were involved in the study. A pre-survey was administered to all

participating students and a content assessment was administered at the conclusion of the program. The content assessment included questions focused on air quality and on research design. Treatment group students also completed a program evaluation at the conclusion of the program. Students in the treatment group scored significantly higher on the content assessment (both content focused on air quality and content focused on research design) than control group students. In the program evaluation, 34% of treatment group students indicated participation in the project did increase their interest in science and the majority of these students indicated participation in the project was a good or excellent experience. Aspects of the program that might have contributed to its success include the fact that students could generate their own research questions and design their own study. This finding of the importance of student input regarding research questions and study design is in keeping with findings of other researchers (Sadler et al. 2010).

Category Three: Student Apprenticeships

Another approach to engaging students in authentic science is for students to complete apprenticeships with scientists. A review of studies focused on apprenticeships for middle school, high school, college, pre-service teachers, and in-service teachers was completed by Sadler et al. (2010). These researchers examined 53 empirical studies published between 1961-2008. The secondary student experiences fell into two categories: extra-curricular and

classroom-based student-scientist partnerships (SSPs). Some of the reviewed studies were qualitative, some quantitative, and some mixed. Methods primarily included pre- post-questionnaires and surveys, case studies, interviews, and observations. In some studies, the Views of Nature of Science (VNOS) was used to examine students' views of the Nature of Science (NOS). The programs reviewed by these authors tended to take place in the summer. A secondary school student was generally placed with a university professor or graduate student. Sometimes both teachers and students were involved. SSPs generally involved doing research with teachers and sharing data with scientists, sometimes via technology. Scientists had differing levels of involvement in these programs.

Most of the reviewed studies indicate participation in these types of experiences increased student interest in pursuing a career in science and/or broadened students' views of science career options (Sadler et al., 2010). There were mixed findings regarding students' views of NOS. Some studies indicated students developed a more restrictive view of science meaning they felt science was conducted per a prescribed set of steps (scientific method); whereas, others indicated students came to view science as tentative. Explicit NOS instruction, including directly providing information to students about NOS and giving them opportunities to reflect, seemed to have a positive impact. Most of the studies show that student content knowledge increases because of apprenticeship-type experiences.

Research examining how high school students' participation in scientific study under the direction of a university/national laboratory scientist impacted their understanding of scientific inquiry and NOS revealed the importance of explicit inclusion of Nature of Science in curriculum (Aydeniz et al, 2011). Seventeen upper level high school students taking advanced courses completed research in a laboratory setting collecting and analyzing data while being mentored by scientists and graduate students over the course of two semesters. Students learned to use scientific equipment and gained an increased understanding in scientific inquiry. They communicated their findings to the scientific community by way of poster presentations. Students made some gains in understanding of NOS (the importance of creativity and the tentative nature of science) but failed to gain understanding in some areas of NOS (hypothesis formation and theory building). Based on findings, these researchers emphasized the importance of including explicit information about NOS in curriculum.

Urban high school students completed a two-week summer internship on university campuses in a study completed by Burgin et al. (2015). Student selection was based on student interest in science with preference being given to those from groups that are underrepresented in Science, Technology, Engineering, and Math (STEM) fields. Participation was free and students received a stipend. They completed research focused on biofuels under the supervision of chemistry and engineering professors. Students spent one day on

a field trip to an algae farm and all other days were spent working in a laboratory setting. Data was gathered on the experiences of eight high school juniors and seniors by way of pre-and post-questionnaires, observations, and interviews. A focus group interview and mentor interviews were also conducted. Despite the brief nature of this experience, researchers found what they describe as subtle increases in student understanding of NOS; specifically, that science is empirical, culturally-based, tentative, and is conducted by a variety of methods.

Burgin and Sadler (2016) studied a program in which high school students (juniors and seniors) completed a seven-week summer internship working in a laboratory at a university as part of the Authentic Experiences in Science Program (AESP). They completed research focused on biofuels under the supervision of physical science or engineering professors. They either worked directly with the professor or with graduate students. Participating students worked alongside researchers every day and attended seminars and meetings. They had the option of obtaining dual enrollment credit. Students did not have the opportunity to develop original research; instead they worked on existing research projects. Students were placed in three groups. What varied between the groups was the type of NOS instruction received during seminar (explicit, reflective, implicit). Students learned content in each seminar. In the explicit seminar, they received direct instruction on the Nature of Science in addition to content. In the reflective seminar, they were given prompts designed to get them to reflect and respond based on NOS in addition to learning content. In the

implicit seminar, they were only taught content. It was felt that each group was receiving implicit instruction on NOS via their research projects. Data was gathered by way of pre- and post-questionnaires of 30 students and interviews and observations of six of these. Faculty and mentors were also interviewed. The primary interest of these researchers was examining impacts of implicit and explicit instruction on student understanding of NOS. There is disagreement among researchers regarding this topic. One idea is that if the learning experience is sufficiently scientifically authentic, an implicit approach might be sufficient. These researchers argue that apprenticeships programs in laboratory/university settings are the most authentic science learning opportunities to which high school students can be exposed. Understanding of NOS increased for students in each group with the greatest gains being made by those in the explicit seminar group. In each group, a few students exhibited a decrease in understanding of NOS. Some distinctions were noted among specific aspects of NOS. For example, participation in the explicit group seemed to lead to an increased understanding of theories and laws.

Category Four: Museum-Based Experience

Examination of objects in museums can be another means by which students may conduct authentic science. Research involving upper secondary school students participating in a ninety-minute lesson focused on evolution at the Natural History Museum of Denmark was completed by Achiam et al. (2016).

They were specifically examining how objects (in this case feathers and bones) can be utilized by students in an authentic science experience. These researchers examined primary literature to determine how paleontologists utilize such objects in their research. They created a framework specific to paleontology to assess the scientific authenticity of this learning experience using praxeologies. Praxiologies are models of human activity that include tasks, technology (defined as rationale for the technique), and theory. An example praxeology would be a comparison of the wing structure and function of Archaeopteryx to wing structure and function of modern birds. This framework considered the need to deconstruct an experience/activity that a scientist would experience and reconstruct it for students in a meaningful way. For example, while paleontologists examine many specimens over time to look at evolutionary relationships, specific skeletons had to be chosen for students to examine in a brief time for this learning experience. Observations, videos, and audios were made of seven classes visiting the museum and participating in this particular learning experience titled *Evolution: From Dinosaur to Bird*. All observations were examined according to the pre-determined praxeologies. While the subject matter and objects of observation were pre-determined, researchers felt, students had freedom to examine and make comparisons of provided objects as they saw fit and carry on conversations based on these comparisons. Based on their analysis, researchers concluded that more than half of the activities

completed and explanations put forth by the students constituted authentic science in the field of paleontology.

Collectively, the research cited here provides a wealth of information about the authenticity of science learning opportunities available to students and how participation in these learning opportunities impacts students. Several themes emerge from an examination of this research including the need for students to have input in research questions and design; the importance of peer interaction and peer review; and variations in understandings of the practice of science based on variations in research experiences.

Research reviewed here emphasizes the importance of student input into developing research questions and participating in study design. The learning experience examined by Chapman and Feldman (2016) allowed for some student input in that students could put forth ideas regarding study questions and could give input regarding study design. For the most part, however, students conducted research and followed protocols of the supervising scientists. It is important for students to develop questions and participate in research design, not just collect data per pre-established protocols (Sadler et al., 2010). Just because students work in a university or laboratory setting under the direction of a scientist does not guarantee the student will experience an authentic science learning opportunity. In some apprenticeship scenarios, students are given menial tasks and are not allowed to give input or complete tasks critical to the research (Burgin and Sadler, 2016). This might occur because researchers feel

students are not capable, because researchers are busy and taking advantage of the extra pairs of student hands to get the routine tasks accomplished, or because the project timeframe is limited (Burgin et al., 2015).

Importance of peer interaction and peer review are common themes in these studies. (Sadler et al. 2010). Recognition by others (peers and professors) is critical in shaping student science identities (Chapman and Feldman, 2016). Feeling part of a team and giving input can result in an increased understanding of NOS and positive feelings towards science (Burgin and Sadler, 2016).

Students attitudes and views regarding science are likely impacted by the type of scientist with whom they work and the type of research in which they are engaged. This might explain the mixed findings regarding student view of NOS found by Sadler et al. (2010) in their meta-analysis. Work by Burgin and Sadler (2016) indicates student view of the scientific method was impacted by the type of apprenticeship work in which they engaged. If the work was very regimented, as might take place in a laboratory setting with strict protocols, students might be more likely to think scientific research does follow a specific set of steps. Achiam et al. (2016) directly address this in their research focusing specifically on scientific practices used by paleontologists and how to create authentic paleontological learning opportunities for students.

The research reviewed here provides support for the importance of authentic science learning opportunities in enhancing student understanding of

science content, understanding of scientific inquiry, interest in science, and understanding of certain aspects of the Nature of Science. My research expands on this body of work by examining participation in authentic science experiences and student agency. In addition, my research addressed some of the weaknesses of the authentic learning experiences reviewed here in that students asked their own research questions, designed their study including choosing materials. They engaged in review of primary literature, engaged in peer review, and contributed to the body of scientific knowledge by sharing their findings with the scientific community.

Review of Literature Related to Learning Experiences that Impact Student Agency

In their overview of research focused on agency in science education, Arnold and Clarke (2014) found several approaches to research on the topic including a focus on ethnography, anthropology, sociology, and discourse. Their work showed that researchers have a variety of definitions for agency and revealed that the definition employed by the researcher guided the methodology used. They provided a detailed review of five studies completed between 2007-2012 (three focused on capacity to act and two focused on patterns of discourse). They stress the need for researchers to provide a clear definition of agency. An important concern expressed by these authors regarding assessing agency based on student action is the potential for researchers to misconstrue motivation behind student action. Instead, they advocate for assessing agency

based on patterns observed during discourse arguing this eliminates the need to attempt to ascertain intentions. An overview of studies focused on student discourse and those focused on student action follows.

An ethnographic study of eighth grade science students in a rural public school in India was completed by Sharma (2008). The students completed a unit studying electricity in their science class. The focus of the research was to examine student participation in science discourse and analyze the factors that cause a change in this participation. Sharma defines agency, not as something an individual has, but as something an individual enacts during a certain set of circumstances. Further, agency is exercised during dialogue. The typical routine in the classroom studied by Sharma was teacher-led and textbook-based. Inquiry was not part of the curriculum, and most interactions followed the Initiate-Response-Evaluate (IRE) pattern. The nature of the class changed somewhat when students began a unit on electricity. In this rural area of India, electricity is expensive and many households acquire it by way of illegal connections. In addition, families routinely repair electrical appliances rather than replace them, again due to limited income. Because of these practices, students (particularly boys) have some knowledge of electricity. This out-of-school practical knowledge resulted in students taking agentive action in the classroom by asking questions and adding to the classroom dialogue. These questions and comments impacted the content covered in the class by broadening it beyond what was in the textbook.

The tensions between a compliance and engagement in transformative learning were examined by Martin (2016) in an instrumental case study. Martin followed the classroom interaction of three female 7th grade students in a science class in Australia over a period of four weeks. Data was gathered by way of audio, video, observations, student interviews, student work, and teacher lesson plans. In this study, agency was defined as "The capacity for a person to position him or herself in a conversation as responsible for action…" (p. 42). Position was defined as sense of responsibility. When students feel their ideas are important, they are more inclined to engage in discourse in such a way as to contribute meaning. Students, both in whole group and in small group activities, can interact in ways that foster compliance rather than engagement (Martin, 2016). Findings of this research indicate a sense of responsibility toward contributing to meaning is as important as scientific knowledge in group interactions.

An ethnography study was completed of five 9th grade high school students in a physics class focused on action research (Basu et al, 2009). Part of the mission of the non-traditional school attended by these students was a focus on action and leadership. Specifically, these researchers examined what occurred when students were given the opportunity to co-design a lesson. Data sources in this study included student interviews, journals, lab assessments, and portfolios. A more in-depth study was completed with two students who are listed as paper co-authors. Based on the experiences of these two students, the

researchers described critical agency which they state, "…is intimately related to the leveraging and development of identity." (p. 356). Per these authors, critical agency is iterative in that it changes over time as interactions occur and it is generative in that as attempts are successful, confidence increases. Their research shows students benefit when they are given the opportunity to contribute to curriculum decisions including choosing topics of study.

How participation in a unit on climate change impacted high school students' content knowledge, beliefs, and actions was examined by McNeil and Vaughn (2012). The climate change unit was specifically designed to address alternative conceptions and provide information about specific actions that could be taken to minimize individual impact on climate change. These researchers worked with junior and senior level students in three urban high schools. Data was gathered from pre- and post- interviews with 22 students. Student content knowledge pertaining to climate change increased significantly after participation in the climate change unit. Most (86%) of students believed climate change was occurring, this percentage increased to 90% after the unit. While most believed in climate change prior to the unit, they could provide more accurate reasons for the occurrence of climate change after participation in the unit. Prior to the unit of study, half (50%) of students stated they were doing something to reduce their impact on climate change. This number increased to 86% after the unit of study. Students also reported more appropriate actions reflecting their increased

understanding of specific actions they could take to minimize their impact on climate change.

Engaging in particular learning opportunities does not result in students having agency. Rather, learning opportunities can impact student agency (Emierbayer and Mische, 1998; Sharma, 2008). Opportunities to experience empowerment are important during the teenage years when students are trying on various roles (Emierbayer and Mische, 1998). Student agency can be examined in student discourse (Sharma, 2008; Martin, 2016) and student action (McNeil and Vaughn, 2012).

Research on student agency regarding science often focuses on environmental issues. Courses focused on environmental issues are generally not required for graduation. For this reason, students in these courses have usually chosen to take the course due to having an interest in the subject matter. McNeil and Vaughn (2012) focused on student agency regarding climate change, the majority (86%) of the students believed climate change was occurring prior to intervention and half (50%) reported taking some type of action to minimize impacts. These numbers are likely not reflective of junior and senior high school students nationwide. A study completed Basu et al. (2009) occurred in a specialized school with a focus on promoting leadership and activism in the student body. This type of research should be expanded to include courses taken by the more general student body including students that might not express an interest in environmental topics.

Connecting content to situations beyond the classroom that have an impact on students' lives can prompt them to take agentive action (Sharma, 2008). Learning specific information about types of action they can take that will minimize an environmental problem can result in action being taken by students (McNeil and Vaughn, 2012). These findings support the need for students to choose topics of study and research questions based on problems that impact their lives. My research allowed students to ask questions regarding their local community and to engage in original scientific research to answer these questions. I examined if engaging in this authentic learning experience prompts students to take agentive action either through discourse or activity.

Review of Literature Related to Learning Experiences Focused on Ecojustice

Some researchers make a distinction between environmental justice which they define as "unequal distribution of harmful environments between people: and ecological justice which they define as "justice toward nature (McLaren and Houston, 2004). I argue against such a distinction because such a distinction is artificial at best and harmful at worst. *Homo sapiens* are animals having evolved along with other living things from prokaryotic organisms. As such, humans are part of (not distinct from) the environment. Mueller (2009a) states: "Ecojustice is an emerging perspective that addresses the confluence of social and environmental justice, oppression for human and nature, and ecological degradation" (p. 1033). While it is true that less privileged groups of

people are being disproportionally exposed to environmental degradation, all of humanity suffers from global effects of environmental degradation including climate change and loss of biodiversity.

Bowers (2002) suggests that current efforts to educate students regarding environmental issues including what is referred to as ecological crises is hindered by the fact that the educational content is situated in cultural assumptions, referred to as root metaphors. It should be noted that some disagree with the use of ecological crises to urge people to action. Mueller (2009a, b) argues against attempts to urge citizens toward activism by way of ecological crises coming from knowledge generated by the scientific community without a deep understanding of environmental issues. Teaching students about recycling and taking them on nature-based field trips are certainly positive things, but ecojustice education needs to include an analysis of inequities that exists in human interactions with each other and with the environment and how these inequities came to exist and are sustained. This requires what McLaren and Houston (2004) refer to as an ethics of care for other humans and for the natural world.

Examples of root metaphors that are significant in ecojustice pedagogy, as described by Bowers (2002), are progress, anthropocentrism, and individualism. Progress is often defined as altering ecosystems for material gain and is exemplified by a lifestyle focused on consumption. Anthropocentrism is a human-focused view of the world. Humans have standing and other living things

do not, or at least not as much as humans. Individualism places a focus on individual wants and needs over those of the community or ecosystem. Bowers (2002) argues that changing these metaphors is difficult and time consuming and involves examining cultural assumptions. Bowers (2002) further states that an ecojustice pedagogy should include an acknowledgement that some individuals (based on ethnicity and socioeconomic status) are exposed to a disproportionate amount of pollutants (chemicals, wastes, etc.) because of the excessive consumption of resources by others. This pedagogy should include a recognition that costs are often externalized and that things (such as ecosystem services) that do not have a price tag, do nonetheless, have value. Finally, a recognition that we should behave in such a way as to ensure future generations' needs are met should be a focus of ecojustice pedagogy.

Providing opportunities for students to engage in environmental field research in their local communities can result in them taking action to protect the environment in these communities (Ceaser, 2012; Dimick, 2012). Students need support in these endeavors. Despite their vocalization of the need to take action, students are sometimes reticent to do so either because they have a limited sphere of agency or fear of those in power (Bencze, Alsop, Ritchie, Bowen, and Chen, 2015). Environmental action by youth is best supported by both engagement in environmental field research and engagement in civic opportunities in their community (Schusler and Krasney, 2015).

Ceaser (2012) completed an ethnographic case study examining impact of attendance at Our School at Blair Grocery (OSBG), a private non-profit organization, on young adults. The school was defined as providing a critical environmental education (EE) program with a primary goal of empowering the local community to achieve food security by providing locally grown healthy food options. Ceaser's specific research purpose was "…to examine how a critical approach to environmental education (EE) promotes student environmental action." (p. 210). The researcher was a participant observer and conducted group interviews. Findings included the following. The youth-centered egalitarian culture of the program allowed young people to discuss issues that were of value to them. The participants referred to their relationship with others as a "community of practice." They felt everyone should have equal input and take on equal work load. Little action was taken in the community primarily due to the high incidence of crime in the area which limited opportunities for students to engage in the community. Participants did complete a successful project surveying community stores to ascertain the availability of fresh food for residents. Student conversations indicated personal actions had changed because of the experience. For example, some student indicated they began to think more critically about what they eat and how their choices impact the environment, for example opting to be vegan or opting not to eat soybean products.

Research conducted by Dimick (2012) focused on the term "empowerment." Dimick highlighted the problems with the word, namely, the implication that one can only have power if it is given or allowed by another. Dimick went on to create a framework to clarify empowerment. Power is present but might not be exerted in the typical classroom environment. The three-part framework includes social, political, and academic empowerment. An explanation and examples of each type are provided. Social empowerment involves interactions among all involved that are supportive and non-discriminatory. It is present in the classroom when students are respected and their voices are heard. Political empowerment involves a recognition of inequities and an attempt to create an equitable environment. It can occur in the classroom when students have input into curriculum decisions and beyond the classroom when students engage in community activism. Academic empowerment involves students receiving an education that is relevant to their lives and will help them achieve their goals. It occurs in the classroom when students critically analyze content. For example, it is important for students to consider how scientific information is used and who has power regarding such decisions. Once Dimick (2012) created the three-part empowerment framework, it was used to complete a qualitative case study of an Environmental Science class in an urban charter school. Nine African American/black students participated in a study which involved the student-led development of action projects focused on educating others about pollution in a local river system. The

teacher of this class was highly motivated to engage students in social justice and had considerable freedom over curriculum. Despite this, students had difficulty completing action projects they designed. Analysis revealed the primary barriers to success were that students lacked specific knowledge of water quality and how it impacts aquatic ecosystems. Students lamented what they described as a lack of opportunity to do science as part of their projects. Despite their failure to complete projects, empowerment of students was observed in many ways including their willingness to take ownership of curriculum decisions and in their insight into problems they encountered while working on their projects.

The institution of school itself often contributes to a materialistic society that by its nature damages ecosystems. For example, placing an emphasis on preparing students to be career – and college – ready, and equating education level with potential income level links education with consumerism. Shume (2015) argues against the current school accountability system as measured by testing data and in favor of a moral accountability system which provides children with transformative learning experiences toward a more just and sustainable world. My research examined how engagement in such a transformative learning experience impacted students' agency to achieve a more just and sustainable local environment. Teacher and students as co-learners disrupts the traditional student-teacher hierarchical structure, thereby allowing a more balanced power dynamic (Dimick, 2012). This promotes student empowerment (exertion of agency).

The connections between authentic science, agency, and ecojustice are critical to my research. Student participation in authentic science can result in a shift of power such that students feel like part of the research group. While allowing opportunities for students to engage in projects and discussion about environmental topics that influence them and their communities is important, these activities provide them with only limited opportunity to exert agency (Dimick, 2012). Engaging in scientific research is critical for students to gain richer meaning and more robust empowerment. My argument is that participation in authentic science, in the form of original environmental field research, will lead to such a power shift which will enable students to exert agency to achieve ecojustice in their community.

CHAPTER THREE
MATERIALS AND METHODS

Research Setting

Students in my study completed environmental research focused on their local waterways. A variety of tensions regarding ecojustice exist in the local community of the students involved in the study. While these are specific to this community, similar tensions occur in other communities. Categories of tensions include inequities regarding groups of people exposed to high levels of pollutants in their neighborhoods; efforts to create a Greenway for citizens to enjoy nature versus protecting nature; and, construction projects versus stormwater compliance and stream protection.

As is the case with many towns in the Southeast United States, community life as well as business and industry are very much centered around a local waterway. In the study town, this waterway is the local creek. The local creek is part of the Limestone and Dolomite Low Rolling Hills subdivision of the Ridge and Valley Ecoregion (Griffith, Omernik, and Azevedo, 1987). It is a tributary to the nearby river and is part of a major river system. The creek's watershed has a drainage area of 39.4 square miles. Most of the watershed lies within the city limits. The headwaters of the study creek are in an industrial area of town. A fabric mill was built in the late 1800's near the headwaters of this creek. This mill, which was built over the creek, produced clothing and the creek was colloquially called Dye Creek because the creek changed colors based on

which color dye was dumped into the creek on a given day. While this mill has been relocated to a different part of town, the area itself continues to be highly industrialized. The area has also experienced revitalization efforts with parts of the old mill being turned into specialty shops. The local farmers'/craft market is also held there seasonally. The stream itself continues to be highly contaminated in this area both from historic industry contaminants and human sewage from sewage/storm drain overflow (TDEC, 2016). In addition to chemical and biological pollutants in this area, the stream contains physical hazards including industry and construction debris such as nails and other rusted metal. It is not safe for the public to access the stream in this area. The study creek next flows through the city, past the study school and through a city park. After the study creek exits the city, it flows into a local river, a tributary to a major river system in the Southeastern United States, that harbors several endangered mussel and fish species (TDEC, 2016). This river is also the source of drinking water for the city.

The study stream is a typical urban stream in that heavy rainfall results in flash flooding due to rapid runoff from impervious surfaces surrounding the stream. Thus, stream banks have become severely eroded in many areas. This has led to altered channel flow and increased sedimentation in the stream. The entire length of the study stream is on the state's 303D list (TDEC, 2016) of impaired waters because of sedimentation. The city began a greenway along the stream in 1998. Extension of the greenway continues today with the goal of

having it run continuously from the headwaters of the study creek to the local river.

Tensions exist in the community regarding inequities of pollution distribution and use of resources for human enjoyment versus ecosystem protection. Neighborhoods exist along the length of the study creek. Neighborhoods in the upper, most contaminated, regions include areas of subsidized housing. Many of the residents in this area are those with lower socioeconomic status. This community also includes Hispanic immigrants, many recently arrived who tend to speak little English, do not have citizenship and therefore have no say in community decisions, and have a lower socioeconomic status. The pattern of certain groups of people experiencing a disproportionate burden of exposure to pollutants is a common one worldwide.

The greenway consists of a concrete sidewalk running alongside the stream. To install the greenway, riparian vegetation was removed in many areas. Both the installation of concrete, an impervious surface, and the removal of riparian vegetation led to an increase in streambank erosion and instream sedimentation. Choosing a concrete surface rather than a hard-packed dirt surface does allow the greenway to be more accessible to people. A representative example of these tensions as they affected students occurred when students had been routinely monitoring conditions in the stream and upon arriving for routine monitoring, saw the riparian vegetation had been removed. They asked, “What happened to our plants?” Upon investigation, it was revealed

that despite the knowledge of the importance or riparian buffers by the local Public Works Department Stormwater Division, the decision was made to allow removal of the vegetation. A local church group wanted to complete the project as part of a volunteer effort to enhance the greenway by making it look neater and clearing it up such that people could see the creek more clearly when walking on the greenway.

The study community is growing dramatically for several reasons. As mentioned earlier, individuals are moving in from many areas. Some of these are Hispanic immigrants. Others are moving in because of religious organizations including a local university, a private religious school which has expanded its course offerings and increased student enrollment. Individuals are also moving in because of a growth in industry in the area. Thus, there is a great deal of construction. The high school itself is expanding each year. And, new elementary schools are being built in the community.

Another example of tensions that affected local high school students occurred when construction was being done on the high school. A geothermal unit was being installed to save energy. When students completed routine steam water quality monitoring, they noticed muddy water flowing into the stream from a discharge pipe. Tracing the discharge pipe to its source, they noticed dirt was running off the construction site at the school. The contractors had installed a silt fence, but improperly. Students expressed concern and a class discussion was held regarding options for action or inaction. The next day, the city stormwater

engineer visited the class as a guest speaker. Students decided to inform her of the problem. She immediately went out to the construction site and issued a fine to the contractor. This resulted in the silt fencing being re-installed properly.

Research Participants

Research participants include high school juniors and seniors in an Aquatic Biology (Scientific Research) Honors course. These students have already taken courses in Biology I and Chemistry I. This is a small school system with five elementary, one middle, and one high school. Demographics of this school system are summarized as follows. Ethnic backgrounds represented among students in this school system include American Indian (0.4%), Asian (2.3%), Black (13.8%), Hispanic (19.8%), and White (62.7%). Sixty-three percent of students qualify for free and reduced lunch. Students with English as a Second Language comprise 8.3% of the student population. Participation in the study was voluntary. Fourteen of the eighteen students in the course chose to participate in the study.

Intervention

I worked with one class, Aquatic Biology (Scientific Research) Honors for an entire semester (August through December 2017). I presented information about my study during the first week of the semester and invited students to participate. Student consent forms (Appendix A) were used for students age eighteen and over. Parent consent (Appendix B) and student assent forms

(Appendix C) were used for students under age eighteen. Each participating student was a case. The content of the course included information regarding aquatic biology (freshwater and marine ecosystems including aquatic organisms) and scientific research. As a class, students participated in environmental field research of our local creek. They examined water quality, habitat, and biota. They worked with a local biologist to complete a survey of fish living in the creek. Students engaged in a snorkeling survey of aquatic organisms living in a nearby river. Another local biologist gave a presentation to the class describing his work with salamanders in a local river. Students participated in a cleanup event of the local creek helping to organize the event and educate volunteers about how to protect our watershed. Students also participated in a project raising trout in the classroom. In addition to being exposed to the course curriculum, students engaged in original scientific research. They designed an original scientific study. The parameters were that the topic of the study had to involve aquatic biology. As part of their study design, they determined appropriate materials and methods. They conducted their research, gathered and analyzed data, and wrote a scientific paper. They also prepared a presentation of their research. Students engaged in peer review throughout this process. The class, including the teacher/researcher, acted as a team of scientists. Student papers were submitted to the state junior academy of science. In this way students engaged in authentic science including study design, peer review, and contributing to the body of knowledge on their topic.

Data Collection Methods

A qualitative ethnographic case study methodology was employed. Ethnographic research focuses on a group (large or small) that shares a culture. To effectively represent group dynamics in research, the ethnographer should immerse themselves with the group, as a participant observer for example. In addition to observations, other sources are frequently used such as interviews and artifacts (Creswell, 2013). Detailed descriptions are important in portraying the complexity of the group culture of interest. In addition to detailed descriptions, the researcher should look for patterns in the data. Finally, the researcher interprets the data based on the observed patterns (Wolcott, 1994). A subtype of ethnography (critical ethnography), which was utilized for the research described here, focuses on issues of empowerment (Ceaser, 2012; Dimick, 2012). This type of research is important for my study because I wanted to effectively represent student empowerment and could best do that by immersing myself as a participant observer.

Case study research focuses on a case or multiple cases with defined boundaries. Multiple sources of data (observation, interviews, artifacts) are utilized. Case studies can be intrinsic, focusing on documenting a unique case or instrumental, focusing on a specific issue by examining an example case or cases involving this issue (Creswell, 2013). Researchers have focused on the topic of empowering youth to take environmental action in local communities (Ceaser, 2012; Dimick, 2012). Case study research involves detailed

descriptions, analysis of data in which themes emerge, and the drawing of conclusions during which the researcher attempts to assign meaning based on findings (Yin, 2009). In this study, cases are instrumental focusing on the issue of how engaging in authentic science (original scientific research) impacts high school students' agency toward ecojustice in their local community. Cases were defined as individual student's experiences as they engaged in authentic science (original scientific research). Research focused on examining the learning experiences of high school students toward promoting action focused on environmental issues has been completed using qualitative ethnographic case study methodology (Ceaser, 2012; Dimick, 2012).

I gathered data by way of observations, an examination of artifacts, and interviews. I was a participant observer each class and field day for a semester. I took field notes and completed a daily field journal. The field journal was set up with the following three sections: Observations, Analysis, Reflection. I noted what students said, did, and how they interacted with me and with each other. I examined materials created by students including their field journal, rough drafts of their scientific paper, peer review forms, their final scientific paper, and their presentation. I interviewed students three times during the semester. Interviews were conducted before or after school (at the student's convenience) in my classroom. An initial interview occurred prior to the beginning of environmental field research, a second occurred half way through the research process, and the last occurred after students completed environmental field research. The

interviews were semi-structured, and interviews were audio recorded and transcribed. The Interview Assent Protocol is shown in Appendix D. Interview questions were designed to assess the following aspects of student agency as identified by Basu et al. (2009) (leveraging – how students position themselves in discourse or action; identity development – how students view themselves as someone who could take action to protect their local stream; iterative – how students reevaluate and modify knowledge and skills; generative – how students utilize knowledge and skills to expand their sphere of influence; and strategic deployment of resources – how students find and effectively utilize resources). Sample interview questions are shown in Appendix E.

Data Analysis

Data was analyzed and preliminary analysis occurred as it was collected (Maxwell, 2013). Data was cleaned to protect the anonymity of participants. Data analysis software (NVivo) was used to manage and analyze data. Data analysis initially involved an examination of the data to look for answers to research questions. Data analysis continued in an iterative manner during initial coding will lead to the emergence of themes. Students words were used to create codes (Miles and Huberman, 2014). Initial coding was completed separately on observation data, interview data, and artifacts. This coding resulted in broad themes for each data type. Validation of the themes was completed by subsequent coding and triangulation among types of data.

Several validation techniques were used in this qualitative study including prolonged engagement, thick descriptions, and triangulation. Prolonged engagement in the field is necessary to gain a deep understanding of the research setting and the participants as well as to gain participant trust (Creswell, 2013; Rossman and Rallis, 2012). In this study, I was a participant observer who was with the other participants in the field for eighty-five days. Thick descriptions provide details for the reader to gain a greater understanding of the phenomenon being described and they allow the reader to determine if the findings are transferable to a different situation (Creswell, 2013). These descriptions can aid in the identification of patterns and interpretation (Rossman and Rallis, 2012). To facilitate creation of thick descriptions, I took detailed field notes and transcribe audiotaped interviews. Triangulation can be an important validation strategy in qualitative research (Creswell, 2013). Data triangulation focuses on an examination of multiple sources of data based on a recognition of the complexity of the problem being studied (Rossman and Rallis, 2012; Yin, 2009). Information from one source can be examined for confirmation or corroboration of information gained from another (LeCompte and Schensul, 2010). Triangulation of data from interviews, observations, and artifacts was utilized to clarify themes in my study.

CHAPTER FOUR
RESULTS AND DISCUSSION

I will begin this section by restating the purpose of the study. Next, I will discuss my positioning and reflexivity; describe student researchers (research participants); and, define major themes that emerged from an analysis of my data. The purpose of this study is to examine whether participation in authentic science (designing and conducting original environmental field research) impacts students' agency to achieve ecojustice in their community. Areas explored in this study include the following:

- How do students view issues of ecojustice in their local environment?
- What power do students feel they have to take action to achieve ecojustice in their local environment?
- What motivates students to take action to achieve ecojustice in their local natural environment?
- What barriers exist that inhibit students from acting to achieve ecojustice in their local natural environment?

Teacher Researcher Positioning and Reflexivity

I am the teacher of the study class, Aquatic Biology (Scientific Research) Honors. I am also the researcher who completed the study described in this dissertation. And, I am an environmental scientist and an environmental activist. In my classroom, I encourage my students to think of themselves as a team of scientists. They serve as peers and support each other's work. Obviously, I am an authority figure for the students and I grade their work. I encourage them to

think of me as an editor of a scientific journal in which they want to publish their work.

As is the case with all researchers, my research is completed through the lens of my past experiences and current views on the topic I study. I impacted and was impacted by the research process. When I was growing up in the Southeastern United States, I spent a lot of unscheduled, unsupervised time outdoors largely in a wooded area near my home. During these times I formed a relationship with the natural world that exists to this day. In graduate school, earning my MS in Environmental Science approximately twenty years ago, I studied stream ecosystems in detail. I worked ten-hour days outside all summer studying twenty-three stream sites in the Southeastern United States. Specifically, I examined how land use practices impact fish assemblages in streams. Early in this research experience I realized that the research alone, while important and a sufficient contribution in and of itself, was not sufficient for me. I felt the need to engage in activities to raise awareness of the importance of protecting stream ecosystems and to engage in activities to minimize damage to and improved conditions in the streams I studied.

When my children were growing up, I regularly took them to the stream that is the focus of this study. We played in the stream and I taught them about aquatic ecosystems. One day, my son (who was about five at the time) asked if he could pet the water. It was obvious he viewed the water as a living thing and he knew he needed to be gentle with this stream organism.

When I began my teaching career at my current school, I advised my principal I wanted to create a long-term project that would allow my students to complete research of our local stream ecosystem. Every class I have taught for the past twenty years interacted with the stream to some degree. Students monitor water quality, habitat, and stream biota. They clean trash out of the stream. They complete streambank stabilization projects. And, they educate the community about how to care for the stream. In fact, it is my goal to instill a love of nature in my students and to empower them to take action to protect the natural world.

My passion for stream ecosystems guides my choice of research focus and impacts those with whom I work. I shared experiences with my research participants as described by Berger (2015). Throughout this research, I have attempted to establish trustworthiness by using triangulation (observation, documents, interviews); extensive observations (approximately seven hours per week over four and a half months); interviewing research participants on three occasions. I have attempted to engage in reflexivity (Palaganas, Sanchez, Molintas, and Caricativo, 2017) by being self-reflective throughout the research process (research design, data collection, data analysis). In addition, I kept a journal of observations and field notes which included three sections: observations, analysis, and reflection.

Student Researchers

Fourteen student researchers participated in this study (Table 4.1). What follows is a description of each individual and their journey through the environmental field research process, from August through December, based on information from observations over the course of four months, three individual interviews, and an examination of documents including field research assignments, scientific papers, peer review documents, and written reflections.

Table 4.1. Student researcher name (pseudonym), grade, and research focus.

Student Researcher	**Grade**	**Research Focus** *****indicates environmental field research of a local aquatic ecosystem
Patricia	12	*Fertilizers and eutrophication
Robert	11	*Benthic Index of Biotic Integrity in a local stream
Sarah	11	*Comparison of effectiveness of natural versus constructed wetlands
David	12	*Impact of artificial items in a local stream
Anik	12	*Survey of microplastics in a local stream
Julie	11	*An examination of temperature and water flow in two local streams
Rachel	12	*Impacts of urbanization on a local stream
John	12	Animal captivity and enrichment practices
Andrea	12	Herbal medicines used by native peoples
Michael	12	Comparison of plants grown by traditional methods to those grown in and aquaponics system
William	12	Examination of water quality in an aquaponics system with plants and tilapia
Jessica	11	Decomposition rates in aqueous environments
Anna	11	Adaptations of certain breeds of dogs for moving in aquatic environments
Amanda	12	Water quality of tap water in three municipalities

John

John is a senior who is Caucasian and originally from the local community. Family and relationships are important to him and he considers himself to be an over-achiever. He is involved in broadcast productions at school and would like to attend college to pursue a degree in broadcast media. He enjoys being creative and using his imagination. John and his family have been involved in outdoor activities near the water his entire life. They often spend the weekends kayaking and swimming, usually brining their dogs. Prior to completing his research, he felt he wasn't damaging our aquatic ecosystems because "I don't pollute." He felt individuals with knowledge, such as government agencies should make decisions about our local waterways but felt it should be local because, "…obviously the community's going to care, like, what their water pollution and stuff is." He went on to describe his feelings about living in this area and the need to protect our ecosystems. "…one of the major blessings of, like, living in this area is just how beautiful with all the nature and stuff." John felt he had a positive impact because he recycles, but he felt in order to make a larger positive impact, he would need to complete research and get more people involved because he is "only one person." John completed a study examining enrichment for animals in captivity. He spent time observing animals in captivity at a local nature center, interviewing their caretakers and interviewing biologists who work with animals in captivity. Midway through his research, John began to feel he might contact the government to propose we increase recycling efforts.

“Call our governor, or call other people as far as the government programs go, and just kind of propose an idea of what if we had…or even if there was a section in garbage trucks, if they halved it, and half was garbage and half was recycling.” Be he stated if he called the governor, he would “…probably get ignored, to be honest.” As John progressed through his research, he created a documentary depicting animals in captivity at a local nature center. Upon completion of his work, he mentioned that he could invite more people to participate in outdoor activities with him, which he felt would increase their desire to protect the environment. “I mean people, especially in my position, you can start clubs or just…I just invite friends out and we can go hiking.” He felt if people were out in nature, they would want to protect it, reflecting, “I wish to make the public more aware of the wildlife we live alongside and hopefully spark some conversation on the way we look at other species.” He continues to want to pursue a career in filmmaking and would love to film wildlife.

Andrea

Andrea is a senior who is Caucasian and originally from the local community. She loves reading, writing, and music. She would like to attend college to study medicine and eventually become a nurse or FBI agent. Andrea described a time when she went whitewater rafting on a local river with her family from further south. They laughed because they got stuck on a rock. She conveyed that her extended family members, who are not from the local area, really enjoy these activities because they do not have the opportunity to engage

in them in their hometowns. Prior to engaging in research, Andrea felt the government should make decisions about our local waterways because "…they'd have people who are specialized in knowing about certain things that others wouldn't get." Andrea felt she was likely impacting local waterways in a negative way by sometimes inadvertently "dropping or spilling things," and by driving a car which likely had some type of leak or emissions. She felt she could have a positive impact by picking up trash, stating if she picked up trash it would just be a small thing but could have an impact on others. Andrea's research focused on herbal medicines used by native peoples. Midway through her research, Andrea began to feel she could "Probably volunteer more with things like the creek clean up and help more to clean up and be more wary in watching." Upon completion of her research, Andrea discussed the importance of taking care of our streams to protect "…the fish, and invertebrates, and well, crawfish is an invertebrate. Little things like that. Bugs." Andrea discussed how she could have a positive impact on our local environment by sharing information with people in the community, "You can just try to get businesses to be more aware of their impact, I guess, by talking to them or going to other little groups like the environmental club." She spoke of this in a general way and did not have a plan for how this could be accomplished.

Patricia

Patricia is a senior who is Caucasian and originally from the local community. She loves being outside in nature and wants to protect the environment. Last summer she worked at a job that allowed her to camp out and complete trail maintenance. She would like to attend college and study environmental science. Patricia shared how she participated in stream clean up events, once with her mom. She described some work she did last summer with a local conservation group. Her work involved trail maintenance and closing off areas where people, instead of using existing trails, created new trails that were damaging waterways. Patricia said she wanted to do this work because she "loves the outdoors." So, she decided to complete conservation work rather than working fast food all summer. Prior to completing her study, Patricia felt the government should make decisions about our local waterways but added, "I think we should elect people who appreciate the waterways and everything that they have to offer." Patricia felt she was having an impact on local streams by owning horses which can impair streams if they walk through them and if their wastes run off into them. She also said driving her car could have a negative impact if it leaks oil. On the positive side, she routinely participates in projects picking up trash and stabilizing stream banks. She felt she could use "her voice" more which would encourage others to join in. Throughout the study, Patricia expressed a high level of awareness regarding her impact on our streams and exhibited agency by taking specific action to minimize her impact and improve

conditions in our stream. The focus of Patricia's research was an examination of the impact of fertilizers on local streams. Throughout the semester, Patricia struggled with the tension of being an environmental activist who wanted to take action to protect the environment (by way of streambank stabilization projects, creek clean ups, and using her voice to encourage others) and being reticent to be too vocal about some issues because one of her parents works for a company that manufactures catalysts for coal-fired power plants and the other works for a company that runs nuclear power plants, "…being raised in a family that has a father who works for (…) and then a stepmother what works for coal plants, that kind of shuts down your little environmental self in the family." She says is it is difficult to have these conversations because, of course, her parents don't want these industries to go away because they would lose their jobs. In addition to reporting that her original research helped her learn more about local environmental problems, she said participating the stream clean up event "…impacted me the most. Just seeing how much trash was actually in (…) Creek was jaw-dropping. I literally pulled a mattress out of the creek along with tires and even a street sign. Seeing all of this in the creek made me think of all the ways that I have negatively impacted local waterways."

Robert

Robert is a junior who is Caucasian and originally from the local community. He loves outdoor activities like fishing and camping and he likes video games. He would like to go to college and become a veterinarian or

biologist. Robert discussed how his opinions about our local waterways have been influenced by his parents, whether they talked about them being polluted or not. His parents have said the two streams in the city are polluted. He has been kayaking and fishing on one of these streams but does not eat the fish he catches. These streams are tributaries to a larger river system that he and his family enjoying spending time on rafting and boating. There is also a river in the area near a nuclear power plant. Robert's aunt lives near that river and they spend time boating in the area. Prior to beginning his research, Robert felt the major problem with our creek was bank erosion. He felt the Environmental Protection Agency (EPA) or a similar organization should make decisions about the stream stating, "I would say I guess somebody who is knowledgeable on what effect we have on it as far as pollution, or what we put in, and how we're going to be using it in the first place. So, I guess the closest person would be the EPA as far as regulations." According to Robert, he was not having a negative impact on the stream because when he goes out boating, he makes sure no trash gets in the river. And, when he goes fishing, he practices catch and release. He felt he could do more by picking up trash in his community, but didn't think it would have a big impact because he is just one person. Robert's study involved working with a biologist from a state agency sampling macroinvertebrates in two local streams. He then analyzed the data to assess the health of the stream using an Index of Biotic Integrity (IBI). Midway through his study, Robert began to feel he could help the creek by getting other people

involved. He said, “Well, for me, it’s really helped with how I could help my own local area but if I were to tell somebody about it, I figure maybe if they care enough to go out and do something about it, that’s that much area I’m changing. Say, I get one person every mile. That’s kind of unrealistic, but if I get one person for certain amount of area and keep on going that’s a whole lot of change that’s going to happen.” He had a specific idea of a group he could share information with. Robert volunteers with another teacher who cooks food for individuals who have low incomes and/or are homeless. Robert felt he might tell this group about our stream and how to protect it. Upon completion of his study, Robert began to identify himself as a researcher and felt he could find information and share it with the public. He stated the local streams are “…severely impaired as far as turbidity, and I guess, just stream health overall because the findings from (…) Creek were 8 out of 15, which is in the poor category and then the (…) Creek findings were 14…” He identified the source of runoff as local business, industry, and a golf course. He said, “…as a researcher I could find all the information and put it out to the public, and make them realize that, hey, you need to wake up and look at this. You’re doing this wrong.” One specific idea he had was that the local golf course could find something that works better with the environment while still maintaining the grass. Regarding his research, he stated, “It might seem like a small impact, and it definitely will not have an immediate effect, but even the smallest difference can have the

biggest effect on the organisms and the water itself. It won't just help the wildlife; it will help us to have healthier drinking water and cleaner swimming water."

Michael

Michael was only able to participate in one interview so my information on him comes from observations, documents, and one interview. He is a senior who is Caucasian and originally from the local community. He enjoys outdoor activities like hunting, kayaking, fishing, hiking, and other sports. He says his family cares for the environment by recycling. He would like to attend college and become a wildlife biologist. Prior to completing research, Michael felt he has a positive impact on our local creek stating, "For instance, I do the creek cleanup and I've been helping out. I've always been against littering and stuff, so it I see litter on the side I'll pick it up and throw it away and stuff." He felt he could have a bigger impact by encouraging his friends, who litter, to stop littering. Michael completed research focused on a comparison of plants grown in an aquaponics system to those grown in soil. Michael exhibited a confidence in his ability to interact with scientists by contacting an author of a primarily literature article he used as a reference for his study. He asked her to provide some additional details of her work on aquaponics and shared his research plan with her. Subsequent to completing his research, William was able to travel to South America with a group of students to help set up an aquaponics system in an area with limited resources.

William

William was unable to participate in any interviews so information on him comes from observations and documents only. He is a senior who is Caucasian and originally from the local community. He plays sports and enjoys water activities like swimming and snorkeling. He reports that he has difficulty concentrating saying he “zones out.” William would like to go to college and major in architecture. HIs research focused on an examination of water quality in an aquaponics system with plants and tilapia.

Sarah

Sarah is a junior who is Caucasian and originally from the Midwestern United States. She moved to this area with her family about nine years ago. She plays soccer and enjoys hiking. She would like to attend college and eventually earn a PhD. Sarah is considering pursing a degree in genetics or astrophysics. She remembers moving to this area and being amazed by the amount of water. She and her family enjoy spending time around our lakes and rivers. When her extended family visits, they always want to spend time on the water. Prior to beginning research, Sarah felt the primary problems with our local creek included sediment and nitrogen from fertilizers. She felt this might harm organisms that live in the creek and people who eat them. According to Sarah, “Decisions for streams should be made in the city by people in the area near the stream. Decisions for rivers should be made by the state. And, overall control should be federal.” She felt she might be impacting our local waterways by

washing her car in her driveway and dropping things. She felt that she could help by recycling and washing her car at a car wash. Midway through her research, Sarah stated she had begun to think more about organisms that live in our creek stating, “Because, before, I didn’t really think about the organisms that might be living. Because whenever I think of the creek, I don’t really associate it with big fish or anything. So it was interesting to pull a catfish out of the creek when we were doing electrofishing because I never expected that before coming into this class to ever be a possibility.” After participating in a cleanup of our local creek, Sarah stated she could have a positive impact by “drinking less bottled water. Because I see a lot of plastic bottles in the creek.” Upon completion of her work, Sarah identified the major problems with our creek as being trash and bank erosion resulting from urbanization. She felt plants, animals, and potentially humans were being negatively impacted stating, “Well, definitely the plants and animals that are kind of near and in the creek are all affected because it’s their habitat. Also, in the long run I’m sure it has an effect on us as well because water is a very necessary part of our lives, so it could have an effect on us.” Sarah began to see herself as a researcher who could have an impact by sharing her findings, stating “I think it’d be interesting to publish some reports on it because it’s new information that maybe some organizations wouldn’t have.” Subsequent to completing the course, Sarah was invited to present her research at two state level junior science symposia.

Jessica

Jessica is a junior who is Caucasian and originally from the local community. She likes to read, carrying a book with her all the time, and to learn. She would like to attend college to study forensic psychology and eventually become a writer. Jessica shares that she used to spend a lot of time hanging out near the river with her family when she was young and now spends time on the water with her boyfriend and his family. Prior to beginning her research, Jessica felt the major problems with our creek are pollution from industry and roads. She felt "…someone in the corporations that control and know how water is being affected…" should make decisions about our creek based on "What's best for fish, and the organisms, and the plants." Jessica felt she negatively impacted our waterways by driving. On the positive side, she said she always picks up trash when she is walking on the greenway near the creek stating she does it "Because it bothers me, and I wouldn't want to be swimming and living in somebody else's trash, especially if that trash is harmful. Like I always pick up cans. I know those ring thingies, which I know that's a big deal for sea turtles, but it could harm these fish, too." She felt she could have a bigger impact by spending more time picking up trash and making people aware, possibly by putting up a sign. Jessica's research focus was an examination of decomposition in an aquatic versus terrestrial environment. Midway through her research, Jessica felt she could "…try to outreach to people, and get them to know stuff that I know, and just help the stream in general." Upon completion of her work.

Jessica identified the primary problems with our stream are people putting stuff in them (by way of driving, littering, and from factories). She continued to feel she could have a positive impact by not littering herself and by picking up litter.

Anna

Anna is a junior who is Caucasian and originally from the local community. She is involved in several extracurricular activities and is a cheerleader. Attending church is important to her. She would like to go to college and become a nurse or elementary school teacher. Anna's family has a vacation home on a local river and they have spent most weekends there since she was five years old. She calls it her "happy place." Prior to beginning research, Anna felt the primary problem with our local creek is trash. She felt that people who make decisions about our creek "…should actually talk to the people who live on the water and see their thoughts, because we all have different views on it." Anna felt that she and her family have an impact on the environment by picking up trash when they see it and keeping a trash bag on their boat. She wondered if the boat leaks anything into the water and isn't sure about that. She felt she could do more by making people, like her neighbors, aware. Anna completed research examining adaptations certain dog species have for moving in the water. Midway through her work, Anna began to feel "If we inform people about the issues, then they will be more likely to help." However, she felt her age was a barrier stating, "It would be hard because not many people will listen to you if you're younger." Upon completion of her research, Anna felt the major problems

with our local creek were trash and pollution primarily resulting from runoff. She stated, “I think that informing people is a big thing because whenever I started taking the class, I wasn’t very aware of it either. So once I started taking this class, I realized all the problems and that made me think.” She did not have a particular plan about how to inform people other than by creating a website or a club. She said she doesn’t think she will do those things however because “Maybe it’s just that I would be wary that nobody would join in.”

Amanda

Amanda is a senior who is Caucasian and originally from the Southwest United States. She has lived in this area for about twelve years. She identifies herself as a good student, and she would like to attend college and medical school. Amanda remembers a trip her family took whitewater rafting down a local river when she was in the sixth grade. She kept failing out of the raft and they had to pull her back in. One time, when they pulled her back, she had two leeches on her foot. When this occurred, she was scared but also thought it was cool. Prior to beginning her research, Amanda felt the main problems with our local waterways are the amount of trash and oil from boats, “Because I live on the water, and I live in the main channel, so there’s tons of boats going through. If there’s a more busy day, there’ll be more oil on the side of the river than there would be if it wasn’t a busy day. And, I even see people go as far as throwing their trash off their boats into the water.” She felt the county should notify the state of problems, “I think the county should tell the state what’s wrong. And, I

mean the state should have the final say. But I feel like the county should be more involved because there's definitely some things that need to be fixed." Amanda felt she was having a positive impact on the river by never littering and by recycling bottles. She said her family has a pole on their boat they can use to retrieve trash they find in the water, and her dad has installed a device on their boat to prevent oil leaks. Amanda said her dad tries to take care of the waterways, "…he told me, one time, and it was something about how when he was in the military, he went to Australia, I think, and one of the rivers, it was completely destroyed. The ecosystem was because of all the boats they used in it." Because her parents like to keep their lawn in good shape they often use fertilizers and other chemicals. She suggested she could speak to them to see if there are more eco-friendly products they could use. Amanda completed research examining water quality of tap water from three different communities. Midway through her research, Amanda felt she could have a positive impact by recycling more bottles and taking shorter showers. She also said, "I thought of an idea, because we have a bunch of dogs, and they tear up the ground and put the soil into the water and that's probably not very good. But, I told my dad that we should, instead of having the grass right there on the gate, we should put rocks down, like the flat rocks, so they can't dig it up so close. He said that was a good idea." Amanda's findings indicated tap water from the three municipalities was safe to drink. However, she continued to say she would only drink bottled water or filtered water from the refrigerator door. When she gave

her research presentation in class, she mentioned that she feels most people use bottled water or get their water from the fridge door. Later, I asked her about that statement. I asked if she really feels most people get water this way and asked her if she thinks everyone can afford this. Her response was, "… personally, I don't drink tap water because that is something I don't want to risk. And so for all these people that don't have that, I think we should…I don't know. I know it's a money thing, but there should be a way where we should provide healthier water. I know it goes through the filtration system at the plant, but maybe if there was a filtration system installed directly into our homes just like in the pipes…I don't know. I don't know what exactly we could do, but I feel like we should do something." Upon completion of her work, Amanda felt the major problems with the stream included trash and oil from boats, stating, "I guess people absentmindedly just throwing trash in…it doesn't matter where they throw it because there's the wind, and then there's environmental factors that bring it down to the creek. And then some people just throw it straight into the creek, I guess, because they don't really think about how it affects the environment, or how it even affects them."

David

David is a senior who is Caucasian and originally from a coastal town in the Southeastern United States. He has lived in the study site area for about eight years but his family still routinely spends time along the coast. David wants to attend college and study marine biology. He would like to have a career that

involves engaging in scientific research. One of David's earliest memories involves going fishing with his dad at a local river and finding a baby diamondback rattlesnake. He and his dad used go fishing a couple of times per week but not as often over the years. Prior to beginning his research, David felt the primary problems with the local waterways were litter and pollution. He felt the government should make decisions about local waterways, "…because they're going to be able to enforce all the stuff while it's more of the community that's using it and they can see what's wrong and what needs to be changed so they can tell the government what needs to be changed so that it can help be reinforced." David indicated he negatively impacted our local waterways by draining the family's saltwater pool and by driving. On the positive side, his family picks up trash when they are out on the river and recycles at home. He said he could do more by getting a petition to get more people involved like an Earth Day event and find a way to make recycling more available for his community. David's research focused on an examination of artificial materials (tires, concrete block, wood, metal, etc.) in our local stream and its impact on the ecosystem and aquatic organisms. Throughout the semester, David exhibited a high level of confidence in his abilities. On the snorkeling trip early in the semester (August), a former student in the class, who is now a biologist with the Forest Service led the educational part of the program. David made a point of staying near her and engaging in conversation asking about her educational background and discussing his desire to become a marine biologist. Other

students were more reticent to interact with her. Later in the semester (October), students had the opportunity to interact with another biologist, who is a stream researcher and professor at a nearby university. David again, exhibited a high level of comfort interacting with a scientist. He spent time discussing fishing trips his family had taken near the coastline. The biologist had been to that area fishing himself and the two discussed various fish species they had encountered while there. David also frequently took a leadership role, albeit in an understated manner, while working with peers. For example, once he learned how to complete tasks related to maintenance of our classroom trout tank, he taught other students without being asked. He provided the most feedback to, and asked the most questions of his peers regarding their research. For example, he suggested a stream location to Patricia that would be appropriate for her study. Midway through his research, David began to feel he should share the information about problems with litter. He stated, “So, I feel like there should be more…get more public knowledge. That either the people that are doing this might not know what they are doing is illegal and hurting the environment. And by giving that information out there, they could potentially stop. Or just have the public know. Maybe getting more involved in, say, stream cleanups. And then, definitely, just try to tell our local government more that this is going on. You might want to check in on it, and maybe crack down on it a little bit.” Upon completion of his work, David felt the major problems with our local waterways included trash and bank erosion. He continued to feel he would pick up trash but

based on his findings, he came to understand that while some of the artificial objects in the stream can leech chemicals or break into small pieces and this is detrimental to aquatic organisms, he also found that some objects, such as concrete blocks and tires, don't seem to cause problems. In fact, these objects provide habitat and substrate for aquatic organisms. He struggled with the importance of preventing litter and the reality that some items, that were initially litter, might benefit wildlife. He stated, "Well, I know for a lot of these smaller objects like the plastic bags, and the small plastic items, and Styrofoam, and the Coke cans, those provide a lot more of a hazard towards the dietary portion of fish. So they eat microplastics and all that spawn off of them are a lot more hazardous. But as for the bigger objects, I wasn't able to test the rate of which they are actually leaching chemicals, and I wasn't able to find any research that had this specific amount day by day. But I was able to find what they do leech. And it's also kind of a balance, I would feel, because if there are say like these treated wood products, because some copper is actually necessary for plants to grow. However, too much of it will actually kill plants, and invertebrates, and so on, and so forth. And so, there's potentially kind of a balance there that could be made with the copper aspect of it. But then there's also the aspect that there's also pesticides within the treatment process that it's at what level of this does it actually begin to affect organisms within the environment." Subsequent to completing his research, David was invited to present his work at a state-level junior science symposium.

Anik

Anik is a senior whose family is from India. He would like to attend college and earn a degree in Industrial Engineering. He remembers spending time on the local greenway when he was younger and appreciated having access to nature. Prior to beginning his research, Anik felt the major problem with our local waterways was pollution caused by human activity. He felt people with knowledge should make decisions about the waterways stating, “I think that scientists and other experts related to the field of biology and preserving the environment are the people best equipped to make decisions on the preservation of that very environment.” Anik viewed himself as a “good citizen” because he recycles. He is a leader in the school environmental club and tries to conserve resources like energy and water. He felt he could have a larger positive impact as a result of the research he plans to complete, stating, if nothing else, the research will be of benefit to him, but he hopes it can also be used to improve conditions in our local stream. For his study, Anik created a device and method for sampling for microplastics and completed a microplastic survey of our local stream. Midway through his research, Anik began to feel he could have a positive impact by sharing his findings with the local community. He stated, “…I could send it to some local organizations that would benefit from this data.” He went on to add, “I feel like some industrial processes release microplastics. Then I can send it to companies in the (…) area that might release some of this stuff. Or I could send it to the government. Maybe they could use that to help get

better monitoring practices." He did express doubt as to whether the community would care or understand his findings, "…most people are pretty apathetic to environmental issues in general. And there's also a lot of people who don't have the academic background to be able to really understand enough to truly understand what my study's about." Upon completion of his work, Anik felt the major problem with our local waterways was pollution which he described as, "So types of pollution could be plastics, harmful chemicals, anything to upset the health of the organisms in the creek." He no longer felt industry was the main source of these pollutants stating, "I think it's caused by…I think industry is a bit misleading. I would say more along the lines of households that are non-point pollution." At this point, Anik viewed himself as a researcher. He stated, "Well, there's the traditional reduce, reuse, recycle that I can sort of do every day. And then I can also go beyond that and sort of conduct scientific research to impact our ecosystem at a deeper level." Reflecting on his research, he stated, "Even small studies such as my own can have a tremendous impact on the scientific community in the long run, building upon the large foundation of shared knowledge contributed by other scientists. Scientific research shifts the spectrum of methods of environmental conservation beyond the typical reduce, reuse, recycle, and it opens up new possibilities for impactful action." Subsequent to completing his research, Anik was invited to present his work at two state-level junior science symposia.

Julie

Julie is a junior who is Caucasian. She has a large family and is originally from the Northeastern United States and has lived in the study community for about four years. She would like to attend college and major in business and minor in forensics. Eventually, she would like to obtain her master's degree. Julie describes how where she lived previously, there weren't a lot of lakes nearby. Now, her family spends as much time as possible at the lake in the summer. They enjoy swimming and jet skiing. She also enjoys "…just sitting on the rocks when the tides are low and watching the water as it moves through the river." Prior to beginning her research, Julie felt the major problem with our local waterways was pollution which she felt harms both humans and aquatic organisms. She stated everyone should become educated about aquatic ecosystems and "I think that certain officials that know the in-depths of water should decide where our resources go and come from." Julie felt she has both a positive and a negative impact on our local waterways. She didn't' know a specific negative impact, but felt she has probably had one. She cited participating in class activities as a way she had a positive impact on our local waterways, and she could have more of a positive impact by picking up trash near a local river. Her mother was a swimmer and her grandfather owned a boat and they were always on the water when she grew up. As a result, her mother cannot stand seeing trash in the water; once spending an entire day picking up trash near the river. Julie feels if she were to spend more time picking up trash, it

might not have a huge impact, but it would have a big impact on her personally because she would think more about the environment. She said it would be a "…personal remembering of how important the waters are." Julie completed research examining water temperature changes over time in a local stream and river. Midway through her research, Julie began to feel her knowledge level about stream ecosystems was increasing stating, "…I feel like now that I'm starting to understand streams and starting to understand what's harmful and what's helping a stream, I feel motivated to do more for. I spent a Saturday because I was off work, I went out to the (…) River and kind of tried to walk along the path that everybody takes. And there was trash in the river, there was trash on the side of the river. I tried to clean up." Upon completion of her work, Julie felt the major problem with our local waterways resulted from "…it's around a lot of roads, or cement, or sidewalks, and a lot of that ends up running off into the water." Julie continued to feel "At the end of the day, the only thing that I can help with is…to try to clean as much trash as possible." She also indicated she could, and does, tell her friends not to litter.

Rachel

Rachel is senior who is Caucasian and has lived in the local community almost all of her life. She likes to paint and bake. She is experiencing some stress due to her mother's illness and a personal relationship. She would like to attend college and become a chef. Rachel remembers participating in a stream cleanup, which she described as "a lot of fun" during the last school year with

another class, AP Environmental Science. Prior to beginning her research, Rachel felt the State Department of Environment and Conservation should make decisions about our local waterways. Rachel felt that if she did more to clean up the stream, more people would be inspired to help. Her research focus was and examination of the effects of urbanization on stream water quality including pH, temperature, turbidity, conductivity, nitrates, nitrites, phosphates, at three stream sites. When Rachel described her research plan to the class in September, she stated that "…ultimately, I would like to get (…) Creek off of the 303d list." This is a list of impaired water in our state. Midway through her research Rachel felt it would be beneficial for others to know about her research. She stated, "I think people would realize what we're doing to our community and our ecosystem. They would maybe try and pick up trash when they see it and recycle the things that they're about to throw away. Hopefully, people wouldn't throw trash out of their car." Upon completion of her research, Rachel felt the primary problems with our local waterways included sedimentation and pollution. Rachel continued to feel she could have a positive impact by picking up trash around the stream but also indicated she could "…petition our legislators to have better policies, and make more laws to protect our waterways." She expressed pride in her ability to engage in the research process, "I can proudly say I have conducted a real scientific study all on my own, all of my creation, and I will never forget that." She further stated her research was important because "Knowledge is power and if our community is educated, then we can…it opens up a lot of doors."

Themes

An examination of the three types of data, observations, interviews, and documents, revealed three major themes with subthemes (Table 4.2). These are Local Environmental Problems - Causes, Impacts, Solutions; Changing Roles - Gaining Knowledge/Power, Becoming Researchers, Influencing Others; and Impact of Peer Review. Below, I discuss how students talked about these themes and sub-themes in the interviews, supported by my observations and document analysis. In addition, I describe how student's discourse and other action around these themes and sub-themes changed as they progressed through the process of engaging in environmental field research.

Local Environmental Problems - Causes, Impacts, Solutions

Early in the semester, primary to beginning research, students expressed simplistic, general ideas about problems with the stream often describing it as being polluted. When asked to provide more details regarding the pollution, they generally mentioned litter. In fact all students indicated litter was a primary problem they observed and suggested they could do more to prevent the problem and help clean up. Amanda stated, "And, I even see people go as far as throwing their trash off their boats into the water." Andrea said she could "…be better about picking up trash." Robert said, "I guess I could go down to the creek and pick up trash myself out of the waterway." According to Jessica, "…If there's stuff in the water, I always pick it up and put it in the trash."

Table 4.2. Major themes and sub-themes from interviews, documents, and observation data.

Theme	Sub-Theme/Examples
Understanding of Local Environmental Problems	Causes "And I even see people go as far as throwing their trash off their boats into the water." (Amanda) "And I've noticed by (…) Park, there's actually some construction going on around the stream bank. I'm not sure what they're doing there but that's most likely putting the sediment and whatever else they're doing in the stream." (David) Impacts "Sedimentation. Every stream in this area is affected by sediment on the bed which hurts fish habitats." (Patricia) "There's definitely a lot of bank erosion." (Robert) Solutions "I could recycle more." (John) "…I could go down to the creek and pick up trash myself out of the waterway." (Robert)
Changing Roles	Gaining Knowledge/Power "So someone who is in the corporations that control and know how water is being affected because there's stuff that I've learned about that I didn't even think about." (Jessica) "I think we should elect people who appreciate the waterways and everything that they have to offer." (Patricia) Becoming Researchers "Well, I mean, as a researcher I could find all this information and put it out to the public, and make them realize that, hey, you need to wake up and look at this." (Robert) "…so they can use my results to hopefully help with their research, and with local industry and government because maybe they could use that to help get better monitoring practices." (Anik) Influencing Others "So, setting an example for other people, or maybe just helping one little part of the stream would have a bigger impact, eventually." (Andrea) "Well for me, it's really helped with how I could help my own local area but if I were to tell somebody else about it…I figure maybe if they care enough to go out to do something about it, that's that much more area I'm changing." (Robert)

Table 4.2 Continued

Impact of Peer Review	"So, I've been helping some people with their introductions for their paper, helping them write, and then also whenever we were able to critique their presentations whenever they read a scientific article that would use for their reference, I thought everybody including myself was able to help each person." (Sarah) "I've definitely exchanged ideas with them, helping them tailor their study in a way that would be easier to execute." (Anik)

In addition to littering, one student, Andrea, said "…we've got a lot of sediment issues." And Robert stated, "There's definitely a lot of bank erosion." Likewise Patricia mentioned there was a "…problem with the banks."

Students felt the primary solutions to improving conditions in the stream included preventing littering, picking up litter, and recycling. Recycling was frequently mentioned as a positive action people can take to protect our local environment. Examples include "I could recycle more," John. Well my family, we always recycle…" Amanda. "I feel like also doing more to recycle. Just helping separate all the stuff at my house and then taking it down to the recycling near me, since I'm near there every day," David. Ideas about the need for and benefit of recycling persisted throughout the research process. The class completed a semester-long, school-wide recycling project. This project was an existing part of the course but students in the class led the project.

Midway through their research, students continued to identify litter as a primary problem. During this time, the class hosted a community stream clean up event. Several students described this event as having a major impact on them. “It was the stream cleanup that truly impacted me the most. Just seeing how much trash was actually in (…) Creek was jaw-dropping. I literally pulled a mattress out of the creek along with tires and even a street sign. Seeing all this in the creek made me think of all the ways that I have negatively impacted local waterways,” Patricia. Robert noted, “Tons of trash was thrown into the area I cleaned, and it was only one small portion of the whole of (…) Creek. Sarah reported that as a result of pulling so many bottles out of the creek, she stopped drinking bottled water. They began to be more specific in the description of the litter they were observing, and they began to feel they could have an impact by encouraging others not to litter and by picking up litter. David began to notice trash over a period of time stating, “It’s like you go out there one day and see all the same stuff. And then the next day, you come out and there’s more stuff in there. And, it’s not just tires, and the soda cans, and food containers, but there’s a lot of weird stuff that’s getting thrown in there. Like I found Tonka trucks, and baseballs, and a couple of traffic cones.” Robert explained how his individual research allowed him to notice trash in a local creek that he otherwise never would have noticed, explaining, “Honestly, I’ve never really seen what was in the creek due to this low visibility level but for the purposes of my research I had to put on waders and walk around in it. I found tons of trash strewn throughout the

stream such as a full CRT television, parts of a recliner, and I even collected a beer bottle on accident when sampling." Andrea said, "If I see somebody drop something on purpose I'm like, 'hey you should pick that up. That's not a good idea. There's a trash can right there. Why don't you just throw it away?"

As the students engaged in environmental field research, they began to provide more detailed explanations regarding problems (bank erosion, sedimentation, channelization, lack of vegetation in the riparian area) with the stream, and exhibit and understanding of the complexities and competing interests (people want to walk, ride bikes on the greenway and see the stream versus a vegetated riparian area without concrete which would result in a healthier stream ecosystem) involved in potential solutions to these problems. Upon completion of their research, students exhibited a broader understanding of how human activity impacts local streams and began to see that the community as a whole contributes to the problem. They also began to pinpoint more specific problems rather than speaking of pollution in a general way. Robert, mentioned the problem of fertilizers from golf courses and agricultural areas. He also described seeing the impact of sedimentation his entire life but not understanding the causes or impacts of it until now, "I never thought any different of (…) Creek as a child, just that it looked brown like chocolate milk. Now I see the same thing and I think of all the ramifications of how this happened, why it happened, and what effect that it is having on the organisms in and around it. The chocolate brown color is due to high levels of sediment in the water which not only makes it

less appealing to swim in but also could cause problems for the aquatic life that lives in it." Andrea explained, "I think it is probably human activity, and us living in a growing city, and all of the cars that drive by, and the people who walk, and factories, and all businesses and things like that." Patricia elaborated on her earlier comment about bank problems, stating, "Sedimentation. Every stream in this area is affected by sediment on the bed which hurts fish habitats." David said, "And, I've noticed by (…) Park there's actually some construction going on around the streambank. I'm not sure what they're doing there but that's more likely putting the sediment and whatever else they're doing in the stream." Anik began to realize non-point sources of pollution are significant, "I think it's caused by…I think industry is a bit misleading. I would say more along the lines of households what are non-point sources."

As students progressed through the research process, they gained a more sophisticated understanding of problems that exist in our local waterways, what/who is causing them, and what could be done to solve existing problems and prevent additional problems. Their ideas about ecojustice broadened in that initially they focused on litter as being a primary problem. This is understandable as litter is readily visible. At that time the focus was on appearance of the litter, something that would negatively impact people. Midway through and toward the end of research, students noticed more details about types of litter and considered how it would impact aquatic organisms. They also had a greater awareness of other environmental problems such as sedimentation and how that

would impact the stream ecosystem. They noticed when something was occurring in the community, such as construction, and considered how that might impact the stream ecosystem and the organisms living there. They expanded their thoughts on what/who is causing the problems. Initially, their focus was on individuals who were littering and industry (point-source pollution), which they mentioned in a generalized way. Later, they expanded their explanation of what/who is causing the problem to include actions occurring throughout the community (non-point source pollution).

Changing Roles – Gaining Knowledge/Power, Becoming Researchers, Influencing Others

Initially, students did not see themselves as possessing knowledge, ability, and power. As they progressed through the research process, all came to view themselves as having more knowledge, ability, and power. Over time, they acted as leaders, shared their expertise with others, exhibited confidence in interacting with scientists, and came to view themselves as researches. In this way, all students exhibited increased agency with some progressing further than others along this agency continuum.

Prior to engaging in environmental field research, most students felt government entities and corporations should make decisions about how waterways are used and how to protect them. They reasoned that these are the groups who would have specialized knowledge and power. According to Andrea, "…it would need to be state level or further up in the government, federal

level…because they'd have people who are specialized in knowing about certain things that others wouldn't get. So it would be easier for them to figure out how to make it work." Robert felt, "…somebody who is knowledgeable on what effect we have on it as far as pollution…" According to Jessica, "So someone who is in the corporations that control and know how water is being affected because there's stuff that I've learned about that I didn't even think about." Anna felt age was a factor stating, "I think society thinks that older people are smarter and more educated, which is usually the case, but sometimes it's not." Anik felt the people with knowledge are scientists who specialize in biology. Several students felt individuals in the local community should be involved in decision making. For example, Anna felt that the government should make decisions but they should get input from the people who live on the river. And, Sarah felt those near a stream should make decisions for the stream (local) whereas decisions about rivers should be made by the state, and the overall control should be federal. According to David, the local community and government should work together to make decisions about waterways. Patricia expressed the opinion that individuals could have an impact by voting, "I think we should elect people who appreciate the waterways and everything they have to offer."

Early in the semester, students frequently expressed a lack of confidence in their ability to engage in the research process. For example, the first time students walked to the creek to make observations and develop tentative study ideas, John asked about surface tension in various bodies of water. He said he

just didn't want to be incorrect if he suggested a comparison study of surface tension. When students were presenting a review of a primary literature article pertaining to their topic of study, Patricia exhibited frustration during her presentation, stating the study she reviewed was too confusing. Students (Patricia, Sarah, David, Anik, and Rachel) who had taken a different science class (Biology II, AP Biology, or AP Environmental Science) with me previously or had been engaged in my school environmental club, were more confident in expressing their observations and tentative study ideas.

From the beginning students expressed ideas about sharing information with others and getting more people involved. These ideas persisted and became more specific with students developing detailed plans for sharing information. Prior to beginning research, students expressed the following ideas. "So, setting an example for other people, or maybe just helping one little part of the stream would have a bigger impact, eventually," Andrea. "…use my voice probably more, I don't know. Have more people join in, more people clean up the stream…" Patricia. "Working together we can do a lot," Sarah. "A lot of people probably wouldn't care if I tried to show them. But, I think if somebody really, really showed them they would start to listen, maybe they wouldn't, or they'd listen for a little bit," Jessica. "Well, we could help petition kind of a thing where it's kind of like an Earth Day event, kind of, where we could go out and then help…" David. Most students felt one person couldn't have a big impact so it is important to get others involved. But, Julie felt actions matter because they

impact the one who is acting. She said, “It doesn’t have to impact anybody else. It would have an impact on me to remember that there are important things within the water, living organisms, plants. And pretty much anything in the water is important.” She went on to describe this as “…a personal remembering of how important the waters really are.”

Midway through the research process, students began to see themselves as someone with knowledge to share and someone who could have an impact on others. They began to think of specific ways they could share their knowledge. Some students began to communicate with scientists on research topics. While completing literature review for his study, Michael contacted one of the authors of a paper he was reviewing. He obtained additional information about her study and shared information about his own study. Midway through the research process, a local biologist spent the day working with students completing a fish survey of our local creek. David, spent a great of the day speaking with this biologist about a variety of science-related topics. All students began to articulate ideas about information they could share with specific individuals and groups. In most cases, students indicated they could share information with friends, family, and groups within which they were involved. “Share my opinions more. I guess. Or share facts more. So, I don’t know. Tell my fellow horse-riding people…and hopefully let them see my passion and then they would be like…’Oh, she’s really passionate about that. Maybe I could stand to learn about it,’” Patricia. “…try to inform the people that are closer to me about

stuff that I have learned and how it affects out area," Robert. Robert does volunteer work with a group that hosts cookouts for low income families living in the city. He had an idea about sharing information with them at one of these events. "Well for me, it's really helped with how I could help my own local area but if I were to tell somebody else about it…I figure maybe if they care enough to go out to do something about it, that's that much more area I'm changing," Robert. Michael suggested he could share information on social media. While most students had begun to feel they could have an impact on others, some expressed the view that they could have only limited impact. Both Patricia and Anna felt people would likely not listen to them because they are young. John proposed an idea involving calling the governor or other government officials to propose an expansion of recycling availability. Then he speculated, "I'd probably get ignored, to be honest."

Two months into the project, during the stream clean up event, some of the Aquatic Biology students worked in groups to clean the creek and some worked in our educational display area teaching other volunteers about aquatic invertebrates and water quality in (…) Creek. John, Michael, and William helped teach the community including younger students about benthic macroinvertebrates and water quality in (…) Creek. Michael and William were very excited to teach younger students about the invertebrates. We had a table with trays, magnifying glasses, a microscope, petri dishes, and laminated identification pages. William worked with the students from a local Boys and

Girls Club helping them use the laminated reference page to identify invertebrates that had been collected. He was very comfortable with these students and seemed to enjoy helping them.

Upon completion of their research, students continued to articulate specific information regarding what knowledge they could share and with whom they could share knowledge. At this point, their perceived zone of influence had expanded and many of them began to identify as researchers. Andrea expressed the importance of "…talking to the community and making people more aware." Patricia wanted "to inform people about things that they might not know. Before this, I didn't know a bunch of stuff about fertilizers. So, me just putting that out into the world is increasing people's knowledge." John, referring to getting more people involved in outdoor activities in nature, stated "So, I just feel trying to invite more people into that would be good." And, Rachel felt, "Knowledge is power and if our community is educated, then we can…it opens up a lot of doors, the opportunity for not only what we can do, but what we can know."

Upon completion of research, several students identified as researchers. Sarah expressed the desire to publish reports that could be shared with agencies who work to protect the stream, stating "I think it'd be interesting to publish some reports on it because new information that maybe some organizations wouldn't have." Robert stated, "Well, I mean, as a researcher I could find all this information and put it out to the public, and make sure they realize, hey, you

need to wake up and look at this." Anik expressed a desire to expand how he has a positive impact on the environment by share his findings with the scientific community "Well there's the traditional reduce, reuse, recycle that I can sort of do every day. And, then I can also go beyond that and sort of conduct scientific research to impact our ecosystem at a deeper level." He felt the scientific community "…can use my results to hopefully help with their research" and he felt local industry and government would benefit because "Maybe they could use that to help get better monitoring practices."

As students progressed through their engagement in environmental field research, they all exhibited agency development. They began to see themselves as someone who has knowledge and power, can engage in the research process, and can influence others in a positive way. They also exhibited a more sophisticated view of ecojustice issues involving who has standing to make decisions about environmental issues.

Impact of Peer Review

At the beginning of the semester, I explicitly established that in the class, we are a group of scientists who will be providing support to each other as we progress through the research process. I articulated, the goal in every situation is to help each other improve our research. Students provided feedback at all stages from the initial sharing of research ideas to the final presentation of the completed research. Each week students provided a verbal update of their research and others had the opportunity to ask questions and offer suggestions.

Students had deadlines to submit rough drafts and final versions of each section (Introduction, Materials and Methods, Results, Discussion) of their research paper to an online platform. Students read and provided written feedback to their peers throughout the semester. Likewise students provided their peers written feedback based on class presentations. While each student completed an individual, original research project, they sometimes completed field work together. Students were not allowed to complete field work alone so they either went out with a family member, friend, or classmate. For example, Patricia worked with Amanda. Likewise, David, Anik, and Rachel worked together. Amanda described this as beneficial by stating, "…two minds are better than one. So they're not thinking about their project. They're thinking about yours and giving you things like ways to get a better sample or different places they get different samples."

In September, each student provided a general description to the class (their peers) about their research topic. Feedback was given by peers. This practice caused a shift in the dynamic of the group. At this point, each student began to take ownership of their own study and become the expert on their topic. Other students began to feel empowered to provide useful feedback. One example of this shift was when Anik described his desire to complete research on microplastics in our stream. He had completed literature review and could find no information for our specific stream; although, this type of work had been completed in the watershed on a larger river. He, and the entire class came to

realize he would be gathering information no one else had. Further, he would need to devise a technique that would work on a smaller body of water. Another example occurred when Rachel described her plan to study effects of urbanization on our stream. She expressed her desire to provide information for our city leaders and stated her "…ultimate goal is to get (…) creek off of the state 303d list of impaired waters." When Patricia described her plan to study the impacts of fertilizer on our local streams, David suggested a stream in his neighborhood would be appropriate for her study as it is in an agricultural area. Likewise, when Sarah discussed her plan to study natural and constructed wetlands, several students had suggestions for where she could find wetlands in our area.

All students spoke about the peer review process helping them in several ways. They felt they were able to give and receive useful feedback. They also felt supported by peers. This experience gave them agency to seek out more pertinent literature and further develop their research topics such that they considered how their research could be used to address local environmental problems. According to Sarah, "I think it's really good to be able to have an experience where you can get feedback from a lot of people and they're not bashing you or anything like that. But it's good to know what you can work on because I don't think you should ever be just doing something all by yourself, especially something that you might put into the world and say it's credible. I have a lot of friends in this class, and I was kind of afraid that most of them would

kind of take it easy and not really help me in any way. I like the criticism. It kind of helps me. And I was wrong. My peers are willing to help me. They're extremely critical, which is what I need." Anna felt she had something to offer her peers "…I can put a different perspective in for the peer review because I am very observant, and I can see the details in things. So I may not be able to give as much of the science, like you should add this in…but I can help with the layout and stuff."

The process of peer review enhanced agency development in student researchers. They began to view themselves and others as an authority on their research topic. For example, Jessica stated, "Going off Sarah's study, she looked at (two local industries). While they do have some measures in place, I'm sure there's still some runoff from their companies that does get into the streams." And, Julie stated, "As Patricia was showing us at a golf courses, a lot of runoff ends up in the creeks there, and fertilizer can get in, and it's not good for our streams." Students often referred to David as an expert on human objects in streams as well as other issues. They frequently asked for his input. For example, when discussing the impact of man-made objects in streams, Sarah said, "You could ask David about that." Julie looked to Robert as someone who had more knowledge of stream ecosystems than she did and; therefore, someone who could help her stating, "He definitely knows more about streams than I probably do, which helped me a lot because when I didn't understand a

part of my project, I could ask him that day, and he kind of was able to expand on it and kind of help me understand."

CHAPTER FIVE
CONCLUSIONS AND RECOMMENDATIONS

High school students in this study engaged in an authentic science experience over the course of four months. All students participated in a variety of environmental field research activities. For example, all students made several trips to our local creek to complete water quality, habitat, macroinvertebrate, and fish surveys. In addition, each student completed original, individual scientific research focused on aquatic biology. This experience contained all components of authentic science as described by (Chinn and Malhorta, 2002). In addition to these components, it also included extensive peer review. And students contributed to the general body of knowledge on the topic in several ways. All students presented their research to classmates, teachers, and other students. Subsequent to completing research, Michael traveled to South America with a group to establish an aquaponics system (the focus of his research). John shared a documentary he created with the local nature center that allowed him to film at their facility. Sarah shared data she collected at a local wetland with the facility where the wetland was located. Robert shared his data with the state agency biologist with whom he collaborated. Sarah, David, and Anik were invited to, and presented their research at, a state junior science symposium. Each student had a unique journey through this process and those journeys are described in Chapter Four through an agency development framework in the context of ecojustice. Looking

at these journeys as a whole, several conclusions can be made. Over the course of the study, student researchers developed the following: 1. greater awareness of local environmental problems, their causes and impacts; 2. more sophisticated understanding of potential solutions to the problems and means by which stakeholders could participate in achieving these solutions; and, 3. increased agency to address local environmental problems by way of discourse and other action including feeling empowered to share information with the local community, with policy makers, and with the scientific community.

All student researchers exhibited increased agency over the course of their participation in environmental field research. Variation existed in the level of agency exhibited by students prior to the beginning of research and the level of agency exhibited at the completion of research. While all students engaged in environmental field research as part of class work, those who engaged in original individual environmental field research focused on our local waterways (Patricia, Robert, Sarah, David, Anik, Julie, Rachel) versus those who completed other types of aquatic-related research (John, Andrea, Michael, William, Jessica, Amanda, and Anna) exhibited a higher level of agency to achieve ecojustice in their local community at the completion of their research. They were more likely to begin to view themselves as someone with power and knowledge who could have a positive impact. Midway through the research process, these students had begun to see themselves as someone who had helpful information to share. For example, Sarah, who completed research on the effectiveness of natural and

constructed wetlands, wanted to share her findings with local agencies in the form of a report. Robert, who completed research on microplastics in our local stream, wanted to share his results with scientists who might be able to use them for their own research. He also felt he could share his results with local government to help them develop better monitoring procedures. Rachel, who completed research on the impacts of urbanization on our local stream, expressed the goal to get our stream off the state list of impaired waters. Patricia, who completed research on the impact of fertilizers on local waterways, stated she could use her voice to get others involved in protecting our streams. Andrea, who completed research on the use of native plants in holistic medicine; Jessica, who completed research on the effects of an aquatic environment on decomposition; and Anna, who completed research on adaptations various dog species have for moving in an aquatic environment did not exhibit as large an increase in agency to achieve ecojustice in their local community. Students were able to choose their research topic providing it pertained to aquatic biology. Basu et al. (2009), in their examination of critical agency, found that students benefit when they can make decisions such as choosing a topic. All students in my study, chose their research topic and were required to articulate why their research was important. It is possible that those who chose to study our local streams had such an existing passion for them that this contributed to their increase in agency to achieve ecojustice. However, it is still clear that their agency did increase as a result of engaging in this authentic science process.

Similar to Calabrese Barton and Tan (2010), I found that as students began to see themselves as having expertise on their topic of study, they began to feel they could take action.

In addition to participation in environmental field research, other factors were felt to contribute to students' agency to achieve ecojustice. Students' early experiences in nature seemed to have an impact on their view of the natural environment and their responsibility in caring for it. All students described early nature-related experiences with their families which they felt impacted their views about the importance of protecting the environment. Patricia, David, and Julie discussed specific ways a parent influenced them to care for local streams. Some students (Robert, Jessica, Amanda, David, and Julie) reported spending free time enjoying outdoor activities on our local waterways sometimes with family like when they were young, sometimes now with friends. Robert seemed to feel that spending time in nature was an important factor in his motivation to care for it. He suggested if we could get people to spend more time in nature, they might have a similar desire to care for it. He stated, "…if we were to do some type of programs, kind of like the river clean up and stuff and people will go out here and see how bad this is, it might make them realize like…Oh, this is not good. What's going on? So, we better go out there and try to fix it." Students (Patricia, Sarah, David, Anik and Rachel) who had taken a science class (Biology II, AP Biology, or AP Environmental Science) with me previously and/or participated in my school environmental club, exhibited a higher level of agency

at the completion of research. All of my classes and my environmental club have some level of involvement in monitoring and cleaning our local stream ecosystem. However, these classes and this club do not include the extensive level of environmental field research and do not allow for students to engage in original individual environmental field research.

For the most part students exhibited a fairly superficial understanding of ecojustice issues prior to beginning their research. Their understanding of causes, impacts, and solutions to local environmental problems became more sophisticated over time. Prior to beginning their environmental field research, students expressed the best way they could help the natural environment was to recycle and pick up trash. While these practices are beneficial, they are relatively safe, socially acceptable ways to do something positive. This finding emphasizes the argument put forth by McLaren and Houston (2004) that teaching about recycling is not sufficient. Instead there is a need for in-depth analysis of inequities that exist in how humans interact with each other and the environment. Throughout the experience of completing environmental field research, students expanded their ideas of how they could have a positive impact on their local environment, but they continued to focus on recycling and trash pick-up. Amanda articulated how her understanding of how to have an impact was deepening midway through the research process by stating, “I’ve always recycled and done stuff like that but it’s made me more aware, it’s made me feel the need to do more to help.” In spite of students in my study discussing

the need to take action and, in some cases, having a specific plan for how to take action, some still hesitated and felt they were too young or that those with authority would not listen. Students did broaden their understanding of environmental problems to include sedimentation, and came to see we all contribute to the problems (non-point source pollution). They also expanded their ideas about who/what was negatively impacted to include, not just people because of the unattractive appearance of litter, but aquatic organisms impacted by the litter and sediment. In this way they began to exhibit and ethics of care for the natural world as described by McLaren and Houston (2004).

Students continued to have superficial understanding of inequities that exist with regard to access to resources. Robert suggested he could share information about how to protect the stream with the low-income families who attend an event where volunteers cook out donated food for them. Amanda, even at the completion of her research which indicated tap water in three local municipalities is safe to drink, indicated she will continue to drink bottled water. Further, she expressed the idea that most people drink bottled water or use a filter system on their refrigerator door to get their water. When pressed on her thoughts on how families with low incomes could afford bottled water or a refrigerator with a filter system and water dispenser on the door, she said she hadn't thought of that. Regarding those who cannot afford bottled water or a refrigerator with a filter, she stated, "I don't know exactly what we should do, but I feel like we should do something." Anna and Amanda both indicated their

families have homes on the water and often go boating on the water but they felt they were not having a negative impact because they make sure they do not throw out trash. A limitation of my study is that my intervention with students did not include explicit instruction on ecojustice issues. I felt students would come to their own realization of these issues through their environmental field research. While this did happen, it was rudimentary. Some students did begin to recognize tensions that exists in the community in terms of competing interests. They came to understand the complexities involved in attempts to prioritize these competing interests. For example, Patricia expressed her desire to use her voice to educate and encourage others to protect our streams. But, she indicated that because her parents have jobs that involve activities that impact steams in a negative way (one associated with nuclear power and another associated with coal fired power plants) she is reticent to use her voice at home because she understands her family income depends on these practices. Through his research, David came to a finding that while disposing of trash and other items in streams is generally detrimental, some man-made objects that have been discarded in our local streams are not harmful and might actually provide habitat for some aquatic species. Several students in class grappled with the idea that the greenway was helpful in that it provides opportunities for citizens to get out and exercise in nature. And, it helped raise their awareness of and desire to keep our local stream clean. It is also detrimental to the stream because the

creation of it resulted in reduction of vegetation in the riparian area, increase in impervious surface (concrete) near the stream, and increase of bank erosion.

Because of the continual peer review process, students were aware of the research others in class were completing. They began to see each other as having expertise on their research topic. These findings are in keeping with those of Sharma (2008) and Martin (2016). Students began to see themselves and others as having specialized knowledge and, therefore, agency. This resulted in them positioning themselves, taking on responsibility, for their area of expertise. My research highlights the importance of peer review in helping students feel they are part of a team and have expertise on a topic. This supports the finding of Chapman and Feldman (2016) that recognition of others is critical in shaping student science identities. My findings revealed that over time students began to acknowledge the expertise of their peers. This acknowledgement helped students begin to view themselves as someone who has valuable information to share. Burgin and Sadler (2016) found that feeling part of a team and giving input increased positive feelings toward science. Students in my study felt that they were part of a research team, giving each other feedback, encouraging each other, and helping each other with field work.

My study adds to the body of knowledge on the topics of authentic science learning opportunities, agency, and ecojustice. My research allowed students to ask questions regarding their local community and to engage in original scientific research to answer these questions. Like Ceaser (2012) and Dimick (2012) my

study supports the finding that engaging in environmental field research in their local community results in students taking action to protect the environment in that community. My research expands on this body of work by examining participation in authentic science experiences and student agency. In addition, my research addressed some of the weaknesses of other authentic learning experiences in that students in my study asked their own research questions, designed their study including choosing materials. They engaged in review of primary literature, engaged in peer review, and contributed to the body of scientific knowledge by sharing their findings with the scientific community.

Recommendations for practitioners based on the findings of this work include the need to provide opportunities for students to engage in environmental field research, an authentic science experience, in their local communities. The authentic science experience should allow students to choose their own research topic, design their study including choice of materials and methods. This is in keeping with the 'bottom-up' approach described by Wilderman et al. (2004). Their work showed that this type of approach empowers community members involved in stream monitoring. It is recommended that authentic science experiences designed for students involve peer review and the ability of students to share their research beyond the classroom; thereby, contributing to the body of knowledge on topics pertaining to their local environment. In this way, they become the individuals with knowledge and power and begin to see themselves as having agency to cause positive change. As students begin to

view themselves as having expertise on a topic, their spheres of agency as described by Bencze et al. (2015) increase. In my research this was evidenced by students beginning to articulate plans to share information and encourage action, initially with friends, family, and other associates. Upon completion of their research experience, they expanded plans to share information and encourage action to include the community, local businesses, and the scientific community.

Recommendations for additional research on how participation in environmental field research impacts high school students' agency to achieve ecojustice in their community include the need for an examination of the impact of explicit ecojustice education. In addition, it would be beneficial to determine the impact of student engagement in environmental field research over a more prolonged (longer than four months) time frame. Research on whether observed gains in agency reflected in these individuals is sustained over time is important. Most of these students will not pursue ongoing study or a career involving environmental field research. Will participation in such activity as a high school student continue to impact their agency toward protecting their local environment as an adult?

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APPENDICES

Appendix A

Informed Consent Statement

Examining the impact of participation in environmental field research on high school students' agency to achieve ecojustice in their local natural environment

INTRODUCTION
You are invited to participate in a research study. The purpose of the study is to determine how participation in environmental field research impacts high school students' agency to achieve ecojustice in their local community.

INFORMATION ABOUT PARTICIPANTS' INVOLVEMENT IN THE STUDY
If you choose to participate in the study, your classwork including field journal, rough drafts of scientific paper, scientific paper, scientific presentation, and peer review feedback will be examined by the researcher and data will be gathered. The researcher will participate and make observations during class and field labs and will take notes. You will also be asked to participate in three interviews (one at the beginning of the course, one approximately six weeks later, and the last at the end of the course). The interviews will take place at your convenience before or after school and will last about 30 -45 minutes. The interviews will be audio recorded strictly for the purpose of transcription.

RISKS
There are no foreseeable risks other than those encountered in everyday life. You will be giving up your time before or after school on three occasions if you choose to participate in the interview. The interviews will be scheduled at your convenience and you can cancel or reschedule at needed without penalty.

BENEFITS
Your participation in this study will be of tremendous benefit to the body of knowledge about science education particularly as pertains to the impact of environmental field research on high school students.

CONFIDENTIALITY
All information in the study will be kept confidential. Data will be stored securely and will be made available only to persons conducting the study unless participants specifically give permission to do otherwise. No reference will be made in oral or written reports which can link participants to the study.

CONTACT INFORMATION
If you have questions at any time about the study or the procedures, (or you experience adverse effects as a result of participating in this study,) you may

contact the researcher, Jeannie Cuervo, at jcuervo@vols.utk.edu, and (423) 478-1113or her advisor, Mehmet Aydeniz, at maydeniz@vols.utk.edu or (865) 974-885. If you have questions about your rights as a participant, you may contact the University of Tennessee IRB Compliance Officer at utkirb@utk.edu or (865) 974-7697.

PARTICIPATION

Your participation in this study is voluntary; you may decline to participate without penalty. If you decide to participate, you may withdraw from the study at anytime without penalty and without loss of benefits to which you are otherwise entitled. If you withdraw from the study before data collection is completed your data will be shredded.

CONSENT

I have read the above information. I have received a copy of this form. I agree to participate in this study.

Participant's Name (printed) _____

Participant's Signature _____ Date_____

Appendix B

Informed Consent Statement

Examining the impact of participation in environmental field research on high school students' agency to achieve ecojustice in their local natural environment

INTRODUCTION
Your child is invited to participate in a research study. The purpose of the study is to determine how participation in environmental field research impacts high school students' agency to achieve ecojustice in their local community.

INFORMATION ABOUT PARTICIPANTS' INVOLVEMENT IN THE STUDY
If you choose to allow your child to participate in the study, their classwork including field journal, rough drafts of scientific paper, scientific paper, scientific presentation, and peer review feedback will be examined by the researcher and data will be gathered. The researcher will participate and make observations during class and field labs and will take notes. Your child will also be asked to participate in three interviews (one at the beginning of the course, one approximately six weeks later, and the last at the end of the course). The interviews will take place at your child's convenience before or after school and will last about 30 -45 minutes. The interviews will be audio recorded strictly for the purpose of transcription.

RISKS
There are no foreseeable risks other than those encountered in everyday life. Your child will be giving up their time before or after school on three occasions if you choose to allow them to participate in the interview. The interviews will be scheduled at your child's convenience and your child can cancel or reschedule at needed without penalty.

BENEFITS
Your child's participation in this study will be of tremendous benefit to the body of knowledge about science education particularly as pertains the impact of environmental field research on high school students.

CONFIDENTIALITY
All information in the study will be kept confidential. Data will be stored securely and will be made available only to persons conducting the study unless participants specifically give permission to do otherwise. No reference will be made in oral or written reports which can link participants to the study.

CONTACT INFORMATION
If you have questions at any time about the study or the procedures, (or you experience adverse effects as a result of participating in this study,) you may contact the researcher, Jeannie Cuervo, at jcuervo@vols.utk.edu, and (423) 478-1113or her advisor, Mehmet Aydeniz, at maydeniz@vols.utk.edu or (865) 974-885. If you have questions about your rights as a participant, you may contact the University of Tennessee IRB Compliance Officer at utkirb@utk.edu or (865) 974-7697.

PARTICIPATION
Your participation in this study is voluntary; you may decline to participate without penalty. If you decide to participate, you may withdraw your child from the study at anytime without penalty and without loss of benefits to which you are otherwise entitled. If you withdraw your child from the study before data collection is completed your data will be shredded.

CONSENT

I have read the above information. I have received a copy of this form. I agree for my child to participate in this study.

Participant's Name (printed) _____

Parent's Name (printed) _____

Parent's Signature _____ Date _____

Appendix C

Assent Form

Examining the impact of participation in environmental field research on high school students' agency to achieve ecojustice in their local natural environment

INTRODUCTION
You are invited to participate in a research study. The purpose of the study is to determine how participation in environmental field research impacts high school students' agency to achieve ecojustice in their local community.

INFORMATION ABOUT PARTICIPANTS' INVOLVEMENT IN THE STUDY
If you choose to participate in the study, your classwork including field journal, rough drafts of scientific paper, scientific paper, scientific presentation, and peer review feedback will be examined by the researcher and data will be gathered. The researcher will participate and make observations during class and field labs and will take notes. You will also be asked to participate in three interviews (one at the beginning of the course, one approximately six weeks later, and the last at the end of the course). The interviews will take place at your convenience before or after school and will last about 30 -45 minutes. The interviews will be audio recorded strictly for the purpose of transcription.

RISKS
There are no foreseeable risks other than those encountered in everyday life. You will be giving up your time before or after school on three occasions if you choose to participate in the interview. The interviews will be scheduled at your convenience and you can cancel or reschedule at needed without penalty.

BENEFITS
Your participation in this study will be of tremendous benefit to the body of knowledge about science education particularly as pertains to the impact of environmental field research on high school students.

CONFIDENTIALITY
All information in the study will be kept confidential. Data will be stored securely and will be made available only to persons conducting the study unless participants specifically give permission to do otherwise. No reference will be made in oral or written reports which can link participants to the study.

CONTACT INFORMATION
If you have questions at any time about the study or the procedures, (or you experience adverse effects as a result of participating in this study,) you may

contact the researcher, Jeannie Cuervo, at jcuervo@vols.utk.edu, and (423) 478-1113or her advisor, Mehmet Aydeniz, at maydeniz@vols.utk.edu or (865) 974-885. If you have questions about your rights as a participant, you may contact the University of Tennessee IRB Compliance Officer at utkirb@utk.edu or (865) 974-7697.

PARTICIPATION

Your participation in this study is voluntary; you may decline to participate without penalty. If you decide to participate, you may withdraw from the study at anytime without penalty and without loss of benefits to which you are otherwise entitled. If you withdraw from the study before data collection is completed your data will be shredded.

ASSENT

I have read the above information. I have received a copy of this form. I agree to participate in this study.

Participant's Name (printed) _____

Participant's Signature _____ Date _____

Appendix D

Assent Interview Protocol

Examining the impact of participation in environmental field research on high school students' agency to achieve ecojustice in their local natural environment

I. **Researcher:** Your mom (dad, parent, etc.) say that you are willing to help me. All you have to do is respond to some questions. Are you willing to help with this project? If you decide you don't want to do this anymore, all you have to do is tell me. You can just say; I don't want to answer any more questions.

I really appreciate your help. Are you ready? Let's begin.

II. The examiner will use the following procedures during the interview:

- Maintain a pleasant facial expression.
- Give general reinforcement by means of these example comments:

"Thanks for thinking about the questions I am asking and sharing your thoughts."

"Your thoughts are important. I appreciate you sharing."

III. The examiner will use the following procedures at the end of interview:

- If the child wishes to stop during the interview, the examiner will maintain a neutral expression, stop the interview and say "All right, thank you for helping me again. Have a great day."
- When the interview is completed, the examiner will say, "Thank you for helping me again. I appreciate your responses to my questions."

APPENDIX E

SAMPLE INTERVIEW QUESTIONS

Interview One: This interview will take place prior to the beginning of student environmental field research

1. Tell me about a memory you have that involves on of our local waterways.
   Sample Follow Up Question
   Why was this an important event for you and your family?
2. Who do you think should make decisions about how we use the creek/river?
   Sample Follow Up Question
   Why do you think those individuals should make this type of decision?
3. Describe all the things you think should be considered in making decisions that affect the creek/river?
   Sample Follow up Question
   Can you think of any other things that should be considered?
4. What are some problems that exist in our local streams and rivers?
   Sample Follow Up Questions
   Why do these problems exist?
   What/Who is being impacted because of these problems?
   What/Who is not being impacted because of these problems?
   What/Who is benefiting from these problems?
5. What are some things you do that have an impact on our local streams and rivers?
6. What are some things you could do to make things better for our local streams and rivers?
   Sample Follow Up Questions
   What do you think would happen if you did these things?
   What might keep you from doing these things?
   How could you do these things?

Interview Two: The interview will take place when students are mid-way through the research process.

1. What are you discovering regarding our local stream ecosystems?
   Sample Follow Up Questions
   Who else do you think knows about the information you are discovering?
   Who else would you like to share the information with?
   How could you share the information you are discovering?
   If you shared the information, what do you think would happen?
2. What is your level of expertise regarding your topic of study?
   Sample Follow Up Questions
   Who do you think knows more than you about your topic of study?
   How has your level of expertise on this topic changed over time?

How can you increase your knowledge and skills pertaining to this topic?

3. How have you helped your peers with their research?
   Sample Follow Up Questions
   How do you feel your input impacted their work?
   How has their input impacted your work?
4. What are some things you do that have an impact on our local streams and rivers?
5. What are some things you could do to make things better for our local streams and rivers?
   Sample Follow Up Questions
   What do you think would happen if you did these things?
   What might keep you from doing these things?
   How could you do these things?

Interview Three: the interview will take place when students have completed the research process.

1. What have you discovered about our local stream ecosystems?
   Sample Follow Up Questions
   Who would you like to share your findings with?
   What impact do you think sharing your findings will have?
2. What is your level of expertise regarding your topic of study?
   Sample Follow Up Questions
   Do you consider yourself to be an environmental scientist?
   How has your level of expertise on this topic changed over time?
3. How have you helped your peers with their research?
   Sample Follow Up Questions
   How do you feel about your ability to give input on environmental field research completed by others?
4. How has conducting your research impacted the way you think about our local stream ecosystems?
5. What are some things you do that have an impact on our local streams and rivers?
6. What are some things you could do to make things better for our local streams and rivers?
   Sample Follow Up Questions
   What do you think would happen if you did these things?
   What might keep you from doing these things?
   How could you do these things

VITA

Jeannie Long was born in Cleveland, Tennessee. She earned a BA in Psychology and BS in Secondary Natural Science: Biology from the University of Tennessee at Chattanooga. She went on to earn her MS in Environmental Science at the University of Tennessee at Chattanooga. Her thesis research focused on the impacts of land use on fish assemblages in Chattanooga area streams. Jeannie has taught Biology and Environmental Science courses at the high school level for twenty years. She has taught similar courses as an adjunct at the college level.