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Exploring the potential to motivate high school environmental science students with environmental justice: a mixed methods approach

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EXPLORING THE POTENTIAL TO MOTIVATE HIGH SCHOOL ENVIRONMENTAL SCIENCE STUDENTS WITH ENVIRONMENTAL JUSTICE: A MIXED METHODS APPROACH

by

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Dedications

This dissertation is dedicated to my wife Jonna. I could never ask for a more supportive person to remain by my side in all things, including this dissertation. I have always aspired to meet her standard as a science teacher, and this work embodies all that she has inspired me to be. Her ability to deal with a mad scientist and a tortured artist at the same time has been brilliant.

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Abstract

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The purpose of this mixed-methods, design-based study was to explore the potential for socioscientific issues framed by environmental to motivate high school environmental science students. The embedded design began and ended with a survey of student dispositions, and included interviews of particular students in an effort to capture views of general and personal dispositions. Statistical analyses uncovered a moralistic approach to environmental decision-making, and a positive outlook of the future, including the confidence to solve environmental problems. Students revealed an abstract notion of the environment that requires innovative approaches to teaching environmental science, and view scientists as essential change agents in the face of environmental challenges. In addition, a socioscientific approach framed by environmental justice empowers as well as motivates students. However, a STEM-based approach alone is insufficient to motivate high school students. The data from this study suggests the need to changes in environmental science pedagogy as well as a critique of the Next Generation Science Standards.

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Chapter 1

Introduction

The National Science Foundation (2000) ushered in the 21st century with a critical look at our nation's strategies to deal with unprecedented environmental challenges. Humans have impacted every natural system on Earth. Humans have transformed or changed more than half of Earth's land surfaces (Hooke & Duque, 2012). Primarily, we have altered the land for habitation, agriculture, and rangelands. Exponential demand and use of freshwater resources has led us to redirect rivers and construct reservoirs (Winter, Harvey, Franke, & Alley, 2013). Fertilizer production and fossil fuel combustion has led to an imbalance of the nitrogen cycle, which in turn has led to a cascade of environmental problems including nutrient imbalances in, and acidification of, aquatic ecosystems (Gruber & Galloway, 2008). Accidental species introductions, habitat alterations, and other perturbations, have led to biological invasions of non-native species (Essl et al., 2015). Furthermore, current extinction rates are 1,000 times higher than natural background rates of extinction, and future rates are likely to be 10,000 times higher (De Vos et al., 2015). Finally, but not least of all, the IPCC (2014) has reported with greater certainty on the anthropogenic cause of climate change due to global warming. The risks and impacts of climate change are interrelated to the aforementioned environmental problems. Overall, these alterations, which affect human health, climate, biodiversity, and critical ecosystem services, know no boundaries and therefore stand to have serious social, environmental, and economic consequences.

However, the environmental impacts of our activities are not suffered equally around the globe, or across the nation. Low-lying nations and poor coastal communities

are especially at risk of flooding due to sea level rise (Hansen, Sato, Ruedy, Lo, Lea, & Medina-Elizade, 2006). Closer to home, Guyette (2015) exposed the problems of municipal water pollution and availability in cities like Philadelphia, Baltimore, and Flint as human rights violations. Through a hypothetical metric called the Kuznets Curve, Stern (2014) demonstrated the potential for environmental degradation to persist in impoverished communities, whereas environmental conditions improve with increasing per capita income.

The federal government has renewed interest in maintaining a strong workforce of citizens prepared to create strategies to prevent, mitigate, and minimize the threats to our national security and livelihood (U.S. DOE, 2015). However, our nation is falling behind on international comparisons of science proficiency, an indicator of our ability meet those challenges. International comparisons on student achievement in science reveal the shortcomings of our education system, as PISA, NAEP, and ACT results show the U.S. mired in the middle of the pack of testing countries (Achieve, Inc., 2014; OECD, 2012). On the 2003 PISA test, U.S. students ranked 20th on science literacy among 29 OECD countries and behind three of the 11 non-OECD countries (Kuenzi, 2008). Hanushek (2014) pointed out U.S. scores have been stagnant for the last decade, while other countries (especially developing nations such as Qatar and Kazakhstan) have made significant gains. Furthermore, other economic powers such as Germany and Israel show improvement. According to the Carnegie Foundation, whose study provoked the development of new science standards, preparing our students is essential to better prepare our students to succeed in the global economy (Achieve, Inc., 2014). The Foundation's report also noted the major advances that have occurred in science itself,

and in our understanding of how students learn science effectively. International comparisons would appear to prioritize economy over ecology.

The prospects for encouraging students to pursue science, let alone succeed academically, appear grim. The federal government has responded with a STEM (Science, Technology, Engineering and Math) initiative for those disciplines, which encompass skills that are necessary to be successful in the 21st century, including problem-solving, gathering and evaluating evidence, and making sense of information (U.S. DOE, 2015). The National Math + Science Initiative (2016) painted a dismal picture of the state of STEM education in America. The number of American students pursuing or completing STEM majors continues to decline. In addition, an inadequate amount of teachers are prepared to teach these subjects. Furthermore, there is a widening achievement gap based on socioeconomic status, ethnicity, and gender among students' interest in pursuing these fields; the job prospects continue to increase. Women, first-generation Americans, and people with disabilities remain under-represented in both STEM careers themselves as well as in STEM education.

Rodriguez (2014) pointed out that the federal government has indicted teacher quality as a source of national shortcomings in student math and science achievement, whereas Kuenzi (2008) recognized that teacher quantity is also an issue. Among the nation's 1.4 million public secondary school teachers, 11.4% reported science as their main teaching assignment on the Schools and Staffing Survey (SASS), which was last administered in the 1999-2000 school year. Research on teacher quality conducted over the last 20 years revealed that, among those who teach science, having a major in the subject taught has a significant positive impact on student achievement; however, only

11.2% of the high school science teachers as of 2004 had at least a minor in a scientific subject (Kuenzi, 2008).

With this scenario in mind, the Committee on STEM Education (CoSTEM), a multi-agency group, created a five-year strategic plan to increase STEM instruction as well as public and youth engagement in STEM education and activities, especially for under-represented groups. However, there are those who question whether science and other disciplines should be overshadowed by STEM initiatives at the expense of other potential benefits of science education, including character development, an understanding of the nature of science, and science for activism and citizenry (Chesky & Wolfmeyer, 2015; Hodson, 2004).

Science Education Reform

Thus, the purpose of teaching science comes into question. Are we teaching students in order to confront the environmental challenges we all face; to develop a workforce, with the opportunity for students to have promising career choices; or to raise civically active citizens? Efforts to reform science education were renewed in light of the national situation, on a foundation of scientific literacy.

Scientific Literacy

The OECD (2012) concluded the failure of students to demonstrate literacy of all types indicates that they will only be able to handle simple tasks, struggle to pursue further education, and therefore will struggle throughout their lives. An analysis of the intersection of the Next Generation Science Standards and the Common Core State Standards in literacy showed that science can support literacy goals (Rhodes & Feder, 2014). Despite their recognition of the novel approach to teaching science *through*

literacy, Rhodes and Feders' (2014) findings portray science (and presumably the skills taught through science) as secondary to literacy itself. Science education may become more difficult if teachers are expected to simultaneously address the immediate issue of the achievement gap in literacy, and the forward-thinking mission of preparing students for college, career, and citizenry through STEM education.

Critical pedagogy theorists would question the motive for scientific literacy. Rodriguez (2014) asserted that the alignment of the two sets of standards amounts to encroachment by the federal government on individuals via institutionalized thinking. Spring (2008) extended this standardization in light of globalization, as he identified international comparisons of PISA scores as the driver of curricular reform. Niblett (2014) revealed the positive role that anti-oppressive education, in the form of activist education, has to transform teachers and students. Meanwhile, he also showed how social change can be effected in schools and local communities through this pedagogy. However, teachers need to attend to competing goals in their classrooms. Dimick (2012) showed how students are empowered by local, socially just projects that leverage their roles as agents of change, requiring a balance between forces induced by national and local policies and activities that foster equity and empowerment through environmental science education. Therefore, the recognition of large-scale forces foments questions about the purpose of advancing scientific literacy.

DeBoer (2000) traced the history of meanings of scientific literacy, leading up to the latest wave of education reform that has given us the Next Generation Science Standards. He concluded that scientific literacy has "implied a broad and functional understanding of science for general education purposes and not preparation for specific

scientific and technical careers" (p. 594). Often, scientific literacy addressed what science content people should know in order to apply scientific knowledge and thinking to everyday life. Eventually, scientific literacy came to indicate the habits of mind that reflect the work of scientists, *vis a vis* cognitive skills that allow people to draw conclusions based on data and so forth. Shamos (as cited in DeBoer, 2000) criticized the broad, vague descriptions of scientific literacy, calling instead for a removed approach that disempowered students. He called for mere access to expert advice, along with a personal appreciation of the science-technology enterprise. This perspective creates an immediately inequity in the face of the ongoing democratic motto *Science For All*. Moreover, the direction of movements to define and promote scientific literacy did little to promote connection or consideration of the natural environment outside of appreciation of its beauty (which was often connected to its "truth") (DeBoer, 2000). Not until the turn of the 21st century did environmental literacy emerge as yet another competency.

Environmental Literacy

With a focus on an understanding of ecology, a commitment to problem solving, and cultural sensitivity, Hollweg, Taylor, Bybee, Marcinkowski, McBeth, and Zoido (2011) defined environmental literacy in a framework developed for the North American Association for Environmental Education. Their notably humane approach integrates knowledge with feelings, priorities, motivations, skills, and actions:

> An environmentally literate person is someone who, both individually and together with others, makes informed decisions concerning the environment; is

willing to act on these decisions to improve the well-being of other individuals, societies, and the global environment; and participates in civic life. (p.1)

Most relevant to this study is their list of dispositions that contribute to environmental literacy: "sensitivity; attitudes, concern, and worldview; personal responsibility; self-efficacy/locus of control; and motivation and intentions" (Hollweg, et al., 2011, p. 4).

As a multifaceted domain, environmental literacy can be further subdivided into domains such as climate literacy and energy literacy (U.S. Global Change Research Program, 2009). Central to the discipline of environmental science is sustainability. The United Nation Decade of Education for Sustainable Development (2005-2014) program sought to mobilize the educational resources of the world to help create a more sustainable future. According to UNESCO (2015), Education for Sustainable Development includes the following domains: Biodiversity, Climate Change Education, Disaster Risk Reduction, Cultural Diversity, Poverty Reduction, Gender Equality, Health Promotion, Sustainable Lifestyles, Peace and Human Security, Water, and Sustainable Urbanization.

These issues appear at all scales, from the local to the global. Thus, a high school environmental science course that addresses environmental justice and sustainability would benefit from the approach of glocalization, defined as the meaningful integration of local and global forces (Brooks & Normore, 2010). This approach is appropriately summarized as in the environmental slogan, "Think globally; act locally." Thus, the potential of new science education reforms to empower students as global citizens contributing to a sustainable future emerges from this concept.

Next Generation Science Standards

However, the Next Generation Science Standards appeared faulty as soon as they were framed. Feinstein and Kirchgasler (2015) analyzed the NGSS as insufficient in preparing students to address sustainability. They concluded that the standards rely on a technology-heavy approach to applying environmental knowledge to solve problems that affect all people equally. The NGSS does not offer guidelines on preparing students for the ethical or political challenges they will face in an environmental science course.

In their framework for the Next Generation Science Standards, Schweingruber, Keller, and Quinn (2012) admitted to omitting certain aspects of the behavioral sciences, claiming that it was not their original purpose to include diverse fields such as social sciences, economics, or political science in the K-12 science curriculum. The NGSS follow the tradition of the National Science Education Standards (NSES), the Benchmarks for Science Literacy, the Science Framework for the 2009 National Assessment of Educational Progress (NAEP), and the Science College Board Standards for College Success, while enhancing it with the integration of core ideas and practices from technology, engineering, and math. Schweingruber et al. (2012) claimed that integrating social, behavioral, and economic sciences into science standards was too complex a task, and asserted that such topics related to those other fields are incorporated into curricula and courses in the humanities such as social studies. While the authors admitted that these other fields are important, they simply recommended that the relevant content and practices should be linked with parallel learning and suggest the development of frameworks for teaching those particular subjects. Feinstein and Kirchgasler (2015) proposed that science educators and social studies educators collaborate to combine

pedagogies that provide realistic lessons that prepare students to tackle the challenges of sustainability. Schweingruber et al. (2012) acknowledged that the National Research Council planned to convene a workshop to address relevant core ideas in social, behavioral, and economic sciences.

Sociopolitical Action

There remains no common solution for maintaining our competitiveness as a nation if we continue to ignore the problems of disinterested students. While effective teachers and educational leaders understand that the NGSS do not dictate *what* we teach, prescriptions for *how* to teach may not translate into effective practice without proper reflection and assessment (Feldman & Minstrell, 2000). The NGSS will help the nation's science educators practice inquiry as the quintessential approach to science, but we cannot commit to teaching in an authentic, student-centered, and project-based manner unless our students *want* to learn, and to participate in society regardless of careers.

Meanwhile, the federal mission to encourage students to pursue STEM education and careers in higher education has infiltrated the public school system while relegating the humanities and many other key competencies of education (St. John, Daun-Barnett, & Moronski-Chapman, 2013). Bencze and Carter (2011) cautioned against teaching science in an undemocratic and unproblematic way that fortifies injustice and oppression through what amounts to hypercapitalism. These forces can be opposed in the classroom when teachers create educational environments based on Purkey and Novak's (2008) invitational education theory, which is based on an ethical stance undergirded by five principles: respect, trust, optimism, care, and intentionality. Thus, ethics of both critique (in which we question the purpose of teaching science) and care (in which we address the

needs of students) may lead us to investigate what may be hidden in the curriculum. We may need to turn to the curriculum to investigate what may be hidden there, for better for worse, through the lenses of the ethics of critique, as well as of care (Shapiro & Stefkovich, 2011). In doing so, For instance, Hodson (2004) took an "unashamed" stance on the (Science-Technology-Society) STS framework when he called for politicizing the curriculum to prepare students for sociopolitical action (p. 5). As teachers reflect on these matters in designing lessons, they may choose to approach multi-purpose and transformative strategies that rather than traditional scientific practices that address natural phenomena devoid of political, personal, or social implications.

Citizen science has emerged as one such movement to engage students in participatory science practices, collecting data, but with little purpose other than collecting data to monitor the environment. Mansour and Wegerif (2013) suggested that science students are disengaged because science seems irrelevant to their lives. They proposed participatory lessons that imbue science with social relevance. Such topics would allow them to make a social impact and be (not just feel like) active citizens. Environmental science teaching can cast students in roles along a spectrum of agency. On one end, they could learn science through the STEM framework, preparing them for careers that support our nation's growth. On the other end, they can learn to do science for, and as, a means to challenge the forces in society that lead to environmental, as well as social, injustice (Roth & DeSautels, 2002). The former approach prepares students for the future. The latter approach empowers students while they learn, creating a more seamless connection between school and life, fostering life–long learning (Roth & Lee, 2004).

The Contemporary Science Classroom

As implemented in the classroom, effective science teaching should attend to more than just preparing students for the workforce. There is a valid need to attend to the cultural and racial "mismatch" of teachers and students that can disengage students (Goldenberg, 2013, p. 113). A critical yet democratic stance of *science for all students* substantiates the concomitant need to empower students of all socioeconomic statuses, ethnicities, and other cultural backgrounds, as well as develop personal character through the practice of science. Seeking more holistic solutions to student engagement and motivation will result primarily in higher outcomes in the science class (Adelman & Taylor, 2001). However, given an interdisciplinary and differentiated approach, we may improve student growth in other academic areas, as well as the affective domain.

Taylor and Parsons (2011) proposed that schools could be re-envisioned to fit the needs of all students, rather than attempt to mold reluctant and resistant learners to fit a single standard. Reaching and empowering at-risk learners may reveal new approaches to discipline, which has been a topic of conversation among the building administrators. Towne (2014) even suggested recasting at-risk students as leaders, with an eye on transforming school climates. Thus, the stage is set for reimagining scientists, science teachers, and perhaps most importantly, science students, as change agents.

Problem Statement

As American students lag behind their international counterparts in science based on international test results, the nation loses its footing economically on the world stage. According the US DOE, the solution appears to be the collective STEM fields, which unite science, technology, engineering, and math. However, there are concerns that the

push for STEM education, meant to bring students up to speed compared to their international counterparts, neglects other student and societal needs. The widely accepted solution to this national problem is the state-by-state adoption of the NGSS, which complement the Common Core (Rhodes & Feder, 2014). Together, these sets of standards allege to prepare students for college and careers. However, the NGSS pay little attention to the ethical, political, and social dimensions of science (Feinstein & Kirchgasler, 2015). Placing science in a sociopolitical perspective may be more important than ever, as the teaching of science itself can be seen as inequitable when tracking leads to inferior learning opportunities for disenfranchised students (Yerrick, 2000).

While the NGSS reflect an inquiry-based approach, motivating students through inquiry is not always successful. Tracking is an issue based on special needs as well as cultural factors. Often, tracking itself perpetuates social inequities (Yerrick, 2000). The ongoing drive for "Science for All" continues to overlook marginalized students. Various scholars including Yerrick (2000) cite the bias in scientific literacy, based on perceived ability to acquire it through different instructional means.

Overall, the stress on STEM education has distracted from the role of socio-scientific issues in motivating students to develop a critical voice. Students study science through a protracted scientific method, which extends the exploration of natural phenomena to technological and engineering solutions, without consideration of the role of the scientist or science student in society. Lessons that are relevant to students, especially those who are at-risk, are key to motivating students (Rodriguez, 2014).

Since Weinberg (1972) introduced the concept of trans-science, in which scientific issues are complicated by social, political, and economic implications,

educational researchers and policymakers have attempted to make science education more inclusive of other disciplines. The environmental problems we face in the 21st century are not purely scientific issues. Developing solutions to problems such as climate change, resource extraction and consumption, and pollution requires the consideration of social, political, and economic implications, which have only become more complicated in the ever-changing world.

It is important to examine the topic of motivating students to learn environmental science for a myriad of reasons. As sustainability emerges as a holistic concept that unites the academic disciplines, environmental science becomes a unifying discipline in which to learn the skills and contents that students need regardless of their path. Furthermore, it is essential that students develop scientific literacy that empowers them to make decisions that benefit them as individuals and as citizens (Schreiner, Henriksen, & Kirkeby Hansen, 2005). Motivating students via empowering them through a lens of environmental justice is transformative because they will be encouraged to confront the biases and inequities that environmental justice addresses and that they themselves may face. In doing so, students become more engaged agents of their own education, and of the world around them (Freire, 1970). In an effort to tap into students' intrinsic motivation, it is essential to identify the dispositions that may be leveraged or transformed to support them not only as learners, but also as active participants in their own education and society. This research offers a glimpse into the experiences of students as they become empowered by studying environmental science through the lens of environmental justice, thereby representing a model for transforming education in light of the new curricular science standards, the

needs of today's learners, and the empowerment of teachers as practitioner-researchers and educational leaders.

Purpose Statement

The purpose of this design-based mixed methods study was to explore changes in the dispositions of students in high school environmental science classes in New Jersey as I attempted to empower them through lessons framed by sociopolitical action (i.e. environmental justice). These lessons were developed in alignment with the Next Generation Science Standards and undergirded by sociopolitical action and environmental justice. Per Creswell and Plano Clark (2010), this embedded study began and ended with the quantitative strand of inquiry, which was a survey administered before and after instruction. The findings of the initial survey informed the intervention and gauged overall changes in student dispositions before and after the course. The embedded qualitative strategy complementing the quantitative strand was influenced by narrative inquiry, which allowed me to investigate the lived experiences of individual students through their time spent studying environmental science (Clandinin & Connelly, 2000).

With experience as the essential resource of the study, qualitative data sources included lesson plans, interviews with students, reflective journals, and field notes, as well as documents such as lesson plans. These sources aligned with narrative inquiry as means to express relationships between the researcher and participant, in light of collaboration and interpretation, an approach that Clandinin and Connelly (2000) described as grounded in the relationships of those sharing experiences. As a teacher-researcher, I continued to share in the experience of the lessons I create for my students.

The goal was to document changes in student dispositions towards science, environmental justice, and their own self-efficacy as a result of learning science through a lens of sociopolitical action.

Research Questions

This mixed-method study began with an initial quantitative phase to discover dispositions among the students overall, in addition to apply critical case sampling (following visual inspection of the quantitative data), to highlight potentially unique participants for the qualitative arm of the study (Creswell & Plano Clark, 2010). The collection of qualitative data was embedded in the collection of quantitative data, so the research questions were predominantly qualitative. A fourth research question specifically addressed the mixing of data from the two strands (Creswell & Plano Clark, 2010). This study answered the following questions:

1. How do student dispositions towards science in society change as a result of studying environmental science?
2. How do student dispositions towards environmental justice change as a result of studying environmental science?
3. What insights emerge from the stories told by high school students about their experiences in Environmental Science when taught through the lens of environmental justice?
4. How can these findings be used to improve the overall learning experiences of high school environmental science students in an era of the Next Generation Science Standards?

Definition of Terms

Change agency. In this study, I sought to empower students as change agents. I envisioned the development of a voice of their own to address sociopolitical issues that depend on scientific knowledge. Fullan and Stiegelbauer (1991) described change agents as individuals who take action to alter their own environments. Furthermore, such people use mandates and policies as catalysts to reexamine what they are doing. Therefore, change agents can also be seen as people who question the status quo.

Dispositions. Dispositions are continuously active character traits that lead people to act (Webber, 2013). They are not necessarily mental states, but rather, include thoughts and feelings that influence one's behavior. They are guided by beliefs and attitudes related to values. They may also include visions and expectations for the self or others. (NCATE, 2006).

Engagement. Student engagement refers to the degree of attention, curiosity, interest, optimism, and passion that students show when they are learning (Abbott, 2014). It takes into account intellectual, emotional, behavioral, physical, and social factors. Sometimes confused with motivation, engagement can be observed as the manifestation of motivation (see below).

Environmental justice. The consideration of environmentalism and environmental ethics expands social justice as environmental justice, a social movement that "promotes the fair and equitable treatment of all people with the respect to environmental policy and practice, regardless of their income, race or ethnicity" (Withgott, 2011, p. 26). Environmental justice seeks to provide "protection from

environmental and health hazards and equal access to the decision-making process to have a healthy environment in which to live, learn, and work" (EPA, 2015).

Inquiry. I refer to inquiry as the constructivist teaching approach as I learned how to employ it in my practice as a science teacher. It centers on student collaboration as a way of discovering and transforming knowledge rather than the teacher's delivery of content to each student. Doing inquiry involves science process skills (e.g. developing hypotheses, making observations, designing investigations, analyzing data, developing arguments based on evidence), as well as participation in engaging activities that require critical reasoning in order to understand inquiry itself (Llewllyn, 2005). This study was concerned with facets of inquiry rather than the whole approach, which relies on a post-positivist to understanding the nature of science itself.

Motivation. Motivation concerns the processes that describe why and how human behavior is activated and directed, based on individuals' emotions and beliefs. Sometimes confused with engagement (which is observable), motivation can be inferred from actions and expressions. I concur with Seifert (2004), who proposes intertwining the four main motivational theories (self-efficacy theory, attribution theory, self- worth theory and achievement goal theory) into a holistic view that accounts for the complexity of individual's situations and identities.

Self-Efficacy. This personal attribute is akin to confidence. An individual's belief or judgment about his or her capability is correlated with positive dispositions such as self-worth, and tend to be motivated to achieve and deliberately choose to succeed in a given task (Bandura, 1977; Bandura, 1993). Students who perceive themselves as

efficacious are likely to act strategically (Seifert, 2004). Therefore, self-efficacy is a necessary attribute of a change agent.

Theoretical Framework

First and foremost, the research was framed by moral transformative leadership (Dantley & Tillman, 2010). Through this lens, I conducted research as a means to advocate for democracy and equity and advance a social justice agenda. The very problem statement of motivating students to learn environmental science depends on my own sense of moral transformative leadership, which I strive to cultivate in my classroom, starting with my students. Such an educational leader can act as a change agent for social justice through pedagogy and praxis, which includes research. This perspective also enabled me to invoke the anti-oppressive framework of Kumashiro (2000), which includes education of the other (including the privileged and the marginalized), education about the other, and education that seeks simultaneously to effect change in students and society. This framework will be explored further in Chapter Two.

Transformational teaching theory served as the pedagogy within the context of this research (Boyd, 2009). The theory connects emotional intelligence and transformational leadership to the praxis of teaching. Not only does this transformational approach support effective pedagogy in practice, but it also fosters leadership. Boyd (2009) evoked Bass' (1990) principles of transformational leadership: idealized influence, inspirational motivation, intellectual stimulation, and individual consideration. With this framework serving as my theories in use, I can unite authentically the spheres

of my practice as an environmentalist, science educator, teacher, and educational leader (Argyris & Schon, 1974). These concepts will be explored in more depth in Chapter Two.

In addition, I enact these four roles through a mixed pragmatic-participatory worldview. The pragmatic worldview is often associated with mixed methods and other interventionist research strategies (Creswell & Plano Clark, 2010; Venkatesh, Brown, & Bala, 2013). In addition to the problem-centered, applied sensibility of pragmatism, I contend that the genuine application of research of any kind is to empower people, whether researchers or participants, to effect change. Therefore, a participatory worldview complements a pragmatic worldview. Honoring the tradition of mixed methods research, the transformative-emancipatory approach of Mertens (2010) also permeates my research design, with its over-arching and recursive premise of environmental justice, as an all-encompassing form of social justice. As pragmatism envelopes participation, so does the quantitative strand of the research envelop the qualitative strand. This and the other theories will be explicated further and connected to one another, in Chapter Two, and will serve as the bedrock of the conceptual framework supporting and defining this study.

Delimitations

The study was limited in scope to one specific scientific discipline, environmental science, which already lends itself to sociopolitical action because the major topics readily involve social, political, and economic issues. It was also limited to the lower-track course I teach, for these students would benefit most immediately from the research. This study did not consider other core scientific disciplines (namely, biology, chemistry, and physics) or other educational levels in the P-12 continuum.

My role as practitioner-researcher placed another limitation on the work. This type of interventionist research emphasizes teacher effectiveness and autonomy (Kinsler, 2010). Therefore, this study runs the risk of research bias because my personal beliefs and values are already reflected in the research design. I leveraged the insights of critical friends and other professional colleagues to limit the influence of my personal beliefs and values. The use of narrative inquiry allowed me to prioritize the voice of my students, rather than my own. Through this strategy, I bridged the gap between first- and second-person research and practice (Kinsler, 2010). In addition, triangulation of qualitative data and mixing and merging of data validated the research.

Indeed, validity is a major issue in mixed methods designs and it must be addressed in both strands of data collection and analysis (Creswell & Plano Clark, 2010). Primarily, triangulation validated the mixed methods design, as quantitative and qualitative data were mixed at interpretation (Creswell & Plano Clark, 2010). Thick descriptions of experience supplied by the students via narrative inquiry support validity (Burroughs & Pinnegar, 2001; Cochran-Smith & Lytle, 2009; Mishler, 1990). Furthermore, the reliance on students' voices was authenticated via member checking (Stringer, 2013). Other data interpretations ensured validity via data integration, including parallel integration for member checking, data transformation for comparison, and data consolidation for emergent themes (Jang, McDougall, Pollon, Herbert, & Russell, 2008).

Concern for the students, which undergirds the entire work, dovetails with my stance as a teacher-researcher in light of validity concerns. The primary ethical concern that limited my research was the recruitment of my own students in the research. I

recognized the "peril of easy access" to participants such students (Seidman, 2003, p. 41). I sought their trust, and minimized concerns of power and coercion. To this end, I supplied each participant and their parents or guardians with an informed consent form so that they were cognizant of the scope and sequence of the study. I made every effort to ensure that their decision to commit to, decline, or terminate participation at any time was in no way reflected in their grade or disciplinary record. Participation was not mandated or rewarded. I pursued this study with their best interests in mind, and to empower them by the very content and design of the research. To ensure anonymity, I used pseudonyms that were known only to me.

Significance of the Study

The significance of the research begins in the overlapping arenas of policy and practice, and extends to suggestions for further research. The boundary between policy and practice are blurred because of the overlapping roles of the teacher-researcher.

Policy

Following a statewide gap analysis concerning efforts to implement the Next Generation Science Standards, Browne et al. (2014) highlighted the need for adjustments in instructional strategies, teacher content knowledge, and classroom culture among other factors. This study demonstrates the potential for classroom research to inform these implementation efforts, which requires a paradigm shift in pedagogy and assessment. Strategic implementation will prevent ineffective institutionalization of the NGSS. The implications of the research are such that school leaders should pause before committing to STEM, STEAM (STEM plus Art), and STREAM (STEAM plus Research) programs so that teachers are given the opportunity to see how such initiatives fit into their

programs, and student bodies. Because Schweingruber et al. (2012) admit to omissions in the framework, this study may support efforts to revise the newly-implemented standards, and pedagogy that supports them.

Practice

Concomitantly, the research may influence policy shifts that affect teacher practice. Professional development opportunities may emerge that encourage teachers to develop and evaluate their own interventions. Such practice requires inquiry and reflection that elevates the profession. Furthermore, as the current form of teacher evaluation becomes institutionalized in New Jersey, practitioner-based research in forms such as design-based research, or even action research, may allow teachers a more effective opportunity to improve their craft and demonstrate their effectiveness. To wit, the very act of conducting this research traces my own evolution as a teacher-researcher, agent for social justice, and teacher-leader. The use of narrative inquiry demonstrates the value of qualitative data originating with the students themselves, thereby empowering the stakeholders who matter most. This research design highlights an approach to improving student performance by including them in the work of the teacher, whether through lesson design or through teacher reflection.

Research

This study fills a gap in the literature that addresses the impact of teaching science through the lens of environmental justice, which is under-represented in light of STEM education. It also contributes to the scant literature that reveals student dispositions towards, and motivations for, studying science. Furthermore, the research contributes to the nascent body of literature on the implementation of the Next Generation Science

Standards, which occurred in New Jersey schools in September of 2016. Furthermore, it will contribute to methodological literature in science education research that situates the classroom teacher as participant-researcher, with student voice as a critical and essential source of data (Barton & Tobin, 2002).

Future research may focus on the role of sociopolitical action as a frame for specific topics in environmental science such as climate change, pollution, or resource consumption. In addition, research can center on the use of relevant socio-scientific topics in other scientific disciplines. Social studies research can take the reverse approach, by teaching science as and for sociopolitical action. Educational researchers could demonstrate the ability of the sociopolitical approach to motivate science students in other age cohorts. While the current study did not address individual non-dominant groups, researchers can delineate the effectiveness of the sociopolitical approach among ethnic, gender, socioeconomic, and other cultural groups for greater inclusiveness in science education. Further research can explore the development of students' perceptions of the nature of science, through reflective thinking as suggested by Abi-El-Mona and Abd-El-Khalick (2011) and Schwartz, Lederman, and Abd-El-Khalick (2012). Research agendas can expand to include teacher preparation, by exploring the effects of alignment of teacher epistemology and practice on students' dispositional development (Robertshaw & Campbell, 2013).

Organization of the Dissertation

This mixed method study was designed to explore changes in the dispositions of students in high school environmental science classes in New Jersey through interventions designed to empower them through lessons framed by sociopolitical action

(i.e. environmental justice). This dissertation is divided into six chapters. Chapter One provides the overall context of the study. Chapter Two presents an abridged review of the literature concerning the place of my research in light of student motivation, science education, and environmental justice. Chapter Three outlines the methods for conducting the study. Chapter Four presents the overall findings of the research as they relate to the research questions guiding this work. Chapters Five and Six each comprises a journal article to be submitted for publication in peer-reviewed journals. One article will focus on significant findings, while the other article will focus on practice.

Chapter 2

Literature Review

This abridged literature review, which will support two manuscripts with more comprehensive literature reviews, is divided into multiple sections. First, this review addresses the emergence of environmental literacy as a purpose of science education. Next, it explores instructional issues in motivating students to learn science in inquiry-based settings. Finally, environmental justice is evaluated as a transformative component of science education that adds an element of socio-political action to environmental literacy, and to the learning experience itself. This theme requires an examination of not only what is taught in science classes, but also *how* science is taught.

An investigation into using environmental justice to motivate students to learn environmental science can be situated in the literature beginning with research that is concerned with the purposes for learning science in the first place: scientific literacy, STEM-based motives, and citizenship. Pedagogical issues explored include motivating students to learn through inquiry-based methods, which comprise the pre-eminent strategy for teaching science. Concerns over relevance emerge in light of the sociopolitical nature of science and environmentalism, eliciting reflections on the nature of real-world applications. These concerns are most pressing in light of the environmental concerns of the present day, not to mention the impending implementation of the Next Generation Science Standards. The reviewed scholarship justifies the current study, and concludes with a description of the theoretical framework that guides this study.

Purpose for Learning Environmental Science

According to NGSS Lead States (2013), the purpose for learning science is to prepare students to be "informed citizens in a democracy and knowledgeable consumers." Furthermore, they assert that a solid K-12 science education will prepare them for college and science-related careers in order to support a competitive nation and lead the global economy.

However, scholars such as Schindel Dimick (2015) contested these motives with allegations of neoliberalism in that citizens are called on to take responsibility for environmental problems. Therefore, she asserted, with governments (at the state or national level) removed from responsibility, participation is limited to solving the actual problems through technological and engineering solutions, rather than through civic participation. She sided with scholars such as Chawla and Cushing (2007), Jensen and Schnack (2006), and Schusler, Krasny, Peters, and Decker (2009), who foresee environmental education geared toward the development of "students' civic capacities and dispositions to engage as participatory citizens in relation to environmental issues and concerns" (Schindel Dimick, 2015, p. 3).

Schindel Dimick (2015) recognized the influences of social forces such as neoliberalism on education. Other scholars recognized the environment itself as a social construct that initially provides our habitat, which in turn depends on the sociocultural framework in which we develop our societies (Hodson, 2011; Pedretti & Hodson, 1995). Science can be described as patently value-laden especially when we consider moral obligations to address sustainability (Dimick, 2015). Thus, a critical pedagogy questions the status quo of both environmentalism and environmental education. For example, it

challenges the anthropocentric worldview that places humans above all other organisms (let alone the environment itself) and supports our right to modify environments and exploit natural resources (Schindel Dimick, 2015). Environmental education that rebuts neoliberalism fosters the development of environmentally conscious citizens who confront multiple discourses (Schindel Dimick, 2015). Thus, both the environment and environmental science are socially situated. Therefore, science education can be viewed as a realm of empowerment in addition to employment. However, all citizens are expected to be able to develop the literacy needed to critically consume scientific information, regardless of the application (Schweingruber, Keller, & Quinn, 2012). A review of the literature reveals that environmental literacy is a subset of scientific literacy.

Environmental Literacy

An exploration of the purpose of teaching environmental science necessitates a description of environmental literacy, especially when framed in the context of educational reform. Initially, scientific literacy addressed what science content people should know in order to apply scientific knowledge and thinking to everyday life (DeBoer, 2000). Eventually, scientific literacy came to indicate the habits of mind that reflect the actual work of scientists. Scientific literacy "implies a broad and functional understanding of science for general education purposes and not preparation for specific scientific and technical careers" (DeBoer, 2000, p. 594). Shamos (as cited in DeBoer, 2000) criticized broad definitions of scientific literacy and advocated for awareness instead, with the assurance that expert advice would be available to all citizens. A perspective that fosters mere appreciation of science creates an inequity in the face of the

ongoing democratic motto *Science For All*. Definitions of scientific literacy do little to promote connection or consideration of the natural environment outside of promoting appreciation of its beauty (DeBoer, 2000). Not until the turn of the century did environmental literacy emerge as yet another competency.

With a focus on an understanding of ecology, a commitment to problem solving, and cultural sensitivity, Hollweg, Taylor, Bybee, Marcinkowski, McBeth, and Zoido (2011) defined environmental literacy in a framework developed for the North American Association for Environmental Education. Their notably humane approach integrates knowledge with feelings, priorities, motivations, skills, and actions:

> An environmentally literate person is someone who, both individually and together with others, makes informed decisions concerning the environment; is willing to act on these decisions to improve the well-being of other individuals, societies, and the global environment; and participates in civic life. (p.1)

Most relevant to this study is their list of dispositions that contribute to environmental literacy: "sensitivity; attitudes, concern, and worldview; personal responsibility; self/efficacy/locus of control; and motivation and intentions" (Hollweg, et al., 2011, p. 4). This definition integrated knowledge with feelings, priorities, motivations, skills, and actions. Thus, environmental literacy can be understood as a comprehensive and holistic approach to understanding the natural world and our connection to it.

As a multifaceted domain, environmental literacy can be further subdivided into domains such as climate literacy and energy literacy (U.S. Global Change Research Program, 2009). Most central to the discipline of environmental science is sustainability. The United Nations Decade of Education for Sustainable Development (2005-2014)

program sought to mobilize the educational resources of the world to help create a more sustainable future. According to UNESCO (2015), Education for Sustainable Development includes the following domains: Biodiversity, Climate Change Education, Disaster Risk Reduction, Cultural Diversity, Poverty Reduction, Gender Equality, Health Promotion, Sustainable Lifestyles, Peace and Human Security, Water, and Sustainable Urbanization. The structure of this program would appear to facilitate an outline for topics to be addressed in an environmental science course that was focused on environmental literacy and authentically addressing these global challenges. However, an analysis of the NGSS reveals a narrow approach to these issues (Feinstein & Kirchgasler, 2015). They deemed the NGSS insufficient in preparing students to address sustainability. They concluded that the standards rely on a technocentric approach to applying environmental knowledge to solve problems that affect all people equally. The NGSS does not offer guidelines on preparing students for the ethical or political challenges they will face in an environmental science course. In their framework for the Next Generation Science Standards, Schweingruber, Keller, and Quinn (2012) admitted to omitting certain aspects of the behavioral sciences, claiming that it was not their original purpose to include diverse fields such as social sciences, economics, or political science in the K-12 science curriculum.

However, such efforts to influence education reform may amount to globalization, with the attending accusations of neoliberalism and oppression. Especially if international comparisons of PISA scores drive curricular reform, standardization appears to neglect environmental protection as a major theme (Spring, 2008). Looking at the nationwide implementation of the Common Core State Standards, Rhodes and Feder (2014) found

that while the NGSS strategy of teaching science through literacy can help support basic literacy goals, science becomes secondary to literacy. Rodriguez (2014) asserted that the alignment of the two sets of standards amounts to encroachment by the federal government on individuals via institutionalized thinking. A conundrum emerges: Where does globalization fit into the schema of environmental education reforms that should focus on global problems?

The NGSS follows the tradition of the National Science Education Standards (NSES), the Benchmarks for Science Literacy, the Science Framework for the 2009 National Assessment of Educational Progress (NAEP), and the Science College Board Standards for College Success, while enhancing it with the integration of core ideas and practices from technology, engineering, and math. Schweingruber et al. (2012) claimed that integrating social, behavioral, and economic sciences into science standards was too complex to accomplish, and asserted that such topics related to those other fields are incorporated into curricula and courses in the humanities such as social studies. While the authors admit that these other fields are important, they simply recommended that that the relevant content and practices should be linked with parallel learning and suggested the development of frameworks for teaching those particular subjects. Feinstein and Kirchgasler (2015) called on science teachers and social studies teachers to collaborate in an effort to combine pedagogies to provide realistic lessons that prepare students to tackle the challenges of sustainability.

Motivation to Learn Science

Defining Motivation

Usher and Kober (2012) pointed out that while motivation is an essential part of the educational experience, education reform agendas focus more policy-based issues such as accountability, standards, and teacher quality. They reviewed research that supports mastery-based goals, such as passing assessments and earning acceptance into college, as motivators (Pintrich, 2003). However, such goals may be difficult to set among lower-track students who have no intention of attending college, and place little value on earning good grades for intrinsic purposes. Therefore, Pintrich (2003) offered additional sources of intrinsic motivation: adaptive self-efficacy and perceptions of competence, personal interest, and values linked to personal identity. Thus, a sense of purpose can serve as motivation, which varies among students, and across time (Pintrich, 2003). Seifert (2004) synthesized seemingly competing theories of motivation, including those examined by Pintrich (2003). In addition to mastery, Seifert (2004) identified emotions and beliefs in addition to social and cognitive motivators as valuable to establishing a productive classroom environment. Seifert (2004) contended that affective constructs lead students to strive for mastery, or at least the avoidance of failure. However, he also recognized that the educational experience can lead to learned helplessness and passive aggression when teachers do not consider feelings that elicit positive behaviors when trying to develop adaptive and constructive learning.

More complex than simply liking an activity or subject, interest is a motivational variable that proceeds through four phases that include both cognitive and affective aspects (Jarvela & Renninger, as cited in Sawyer, 2014). First, interest is triggered, and

then may or may not develop into a deeper individual interest. Discrepant events that invite students to inquiry may be used to engage students (Llewellyn, 2005). Such opening activities catch students off-guard with unexpected results, piquing their interest and provoking them to pose questions. Students then become motivated to formulate questions to pursue. Leveraging this strategy in light of environmental justice, students can be engaged by the sheer act of challenging a status quo. Overall, this research will explore the development of interest in environmental science, as it proceeds through three more phases following triggered situation interest: a maintained interest in the situation, emerging individual interest, and a well-developed individual interest, which is sustained by the learner's own curiosity and concern (Hidi & Renninger, 2006).

Interest is an essential construct because it is fluid and malleable based on peer interactions, learning tasks, and learner support (Jarvela and Renninger, as cited in Sawyer, 2014). Lin-Siegler, Ahn, Chen, Fang, and Luna-Lucero (2016) found that students who studied great scientists' struggles to make discoveries were more motivated to learn, and were more successful, than students who learned only about successful scientists. Their findings are more telling, because the positive effects were more pronounced among underperforming students. Pickens and Eick (2009) found that practical applications and hands-on activities motivated lower-track students. Learning activities that facilitated dialogue and built self-confidence were also significant factors. Focusing on intrinsic motivation appears to have the most productive effects, especially among less successful students.

The research can be situated in the identity-based motivation model of Oyserman and Destin (2010), who theorized that motivation is a socially dynamic construct that

depends on congruence between identity and learning experiences. Essentially, students need to feel they can picture themselves being successful in what they are learning, and that those activities are for "people like them" (Oyserman & Destin, 2010, p. 1018). On a macro level, we can consider cultural factors such as race, socioeconomic group, gender, and so forth; on a micro level, we can consider immediate aspects of identity. Special attention to motivating such students becomes more important as students relegated to lower tracks are further marginalized when they become convinced that they cannot be successful, and enter into a subculture that supports deliberate failure as a form of identification (Yerrick, 2000). While analyzing individual perceptions that fuel motivation lead to discussions of self-efficacy theory, student performance on those tasks complicates efforts to situate motivation in self-efficacy (Seifert, 2014). Instead, we may view students motivated by the need to protect their self-value (Seifert, 2014). These scholars focused on motivation to learn science as well as what activities motivate students to learn. As inquiry-based teaching has gained prevalence, scholarship into the meaning of inquiry has also grown.

Inquiry-Based Practices

Inquiry has become the predominant pedagogy that reflects the experiential and constructivist practices of science, yet has been applied to most student-centered, active learning practices. The National Science Teachers Association embraced inquiry as an instructional strategy and used the definition provided by the National Research Council (1996) in its position statement. Scientific inquiry represents the "the diverse ways in which scientists study the natural world and propose explanations based on the evidence derived from their work." This approach to understanding the natural world is empirical

and post-positivist. It reflects both how scientists conduct their research, as well as how teachers can facilitate student learning that centers on students' questions, for inquiry has its roots in the work of John Dewey, whose work stressed active learning and interactions with the natural world (Nathan & Sawyer, as cited in Sawyer, 2014). While the framework for the Next Generation Science Standards does not offer as clear a definition, it builds on these same philosophical underpinnings (Schweingruber, Keller, & Quinn, 2012). While inquiry may reflect authentic scientific practices in which all students can engage, current research reflects a bias in student learning (Brickman, Gormally, Armstrong, & Hallar, 2009; Shaw & Nagashima, 2009; Zohar & Krasinski, 2005). These biases reflect the nuanced learning environment that Seifert (2004) suggested needs to be adaptive and constructivist.

While inquiry has been favored as pedagogy for the sake of learning science itself, research findings become complicated when we look at the students under investigation. On one hand, Dalton, Morocco, Tivnan, and Mead (1997) found that both general education and learning disabled children had greater success learning scientific concepts through supported, constructivist inquiry than through hand-on activities. Attention to cognitive processes was more effective than instruction focusing on simple experience. On the other hand, Shaw and Nagashima (2009) uncovered an achievement gap based on student sub-groups. Their analysis of performance assessments revealed underperformance in inquiry-based instruction by the following student sub-groups compared to their counterparts: Blacks, Hispanics, low socioeconomic status students, males, non-gifted, and special education students (Shaw & Nagashima, 2009).

Motivation and Student Performance

Researchers strived to connect motivational theory to student performance as much as to self-efficacy. Tuominen-Soini, Salmela-Aro, and Niemivirta (2008) highlighted the gap between goal achievement and goal avoidance by considering student well-being. They connected well-being with self-improvement and personal growth, and adjustment problems with avoidance tendencies related to the validation or demonstration of competency. Similarly, Brickman, Gormally, Armstrong, and Hallar (2009) found that students learning science through inquiry as an authentic form of learning gained self-confidence in their abilities. These findings support the creation of a positive learning environment that includes authentic concern for the students, evocative of an ethic of care (Shapiro & Stefkovich, 2011). Furthermore, Ennis (2011) aligned critical thinking skills (such as those developed in science classes) with the potentially necessary dispositions that reflect this ethic.

Despite positive results, Brickman, Gormally, Armstrong, and Hallar (2009) described the challenge of learning through inquiry as a potentially complex and frustrating process. Students can become resistant to learning depending on the level of frustration they experience. Zohar and Krasinski (2005) found that inquiry-based teaching could have contradictory effects on students of different academic levels. Lower-achieving students benefited more from a direct teaching approach rather than the inquiry-based Induced Cognitive Conflict method. Teaching lower level students through inquiry will be challenging, especially if they have not grown up learning in an inquiry-based setting, which the Next Generation Science Standards requires.

Positive correlations between motivation and inquiry-based teaching are available. Through a design experiment, Palincsar, Magnusson, Collins, and Cutter (2001) demonstrated the efficacy of inquiry-based instruction in an inclusion setting. When Daniels and Arapostathis (2005) let reluctant students voice their own opinions in their research, they found that students' sentiments support current motivational theory such that the promotion of student voices can break the cycle of disengagement.

Researchers continued to focus on the interactions between teachers and students, rather than the dispositions, skills, or attitudes of either party. Whitworth, Maeng, and Bell (2013) suggest that inquiry-based settings reflect student-teacher relationships, rather than just a focus on cognitive skills, because of the interactive nature of this pedagogy. In an effort to differentiate inquiry-based instruction, they began with six beliefs described by Tomlinson and Imbeau (2010) as best practices to align with different learning levels based on teachers' ability to modify or tier activities. These tenets stress respect for students, diversity, reflection of our society, equity, and capacity building of learners. Thus, the differentiation of inquiry-based teaching reflects a moral transformative framework (Boyd, 2009). Furthermore, in an empirical study Patrick and Yoon (2004) questioned the assumption that inquiry motivates students. They examined student motivation, thoughtfulness, conceptual understanding, and changes in that understanding. They found that student motivations changed with changes in their understandings. Therefore, it is not only the pedagogy itself that motivates students via the cognitive domain, but also the sense of mastery that implicates the affective domain (Patrick & Yoon, 2004). Therefore, differentiation of motivation is essential in addition to

differentiation of instruction itself, as both require close attention and flexibility on the part of the teacher. Ergot, the focus on interest is crucial to motivating students.

While interest may be developed from a neutral starting point, Fredricks, Blumenfield, and Paris (2004) placed engagement on a spectrum from commitment to alienation by characterizing students' thoughts, feelings, and behavior. By studying conduct and on-task behavior, we may be able to realize how authentic student motivation is. They made supportive recommendations to motivate emotional and behavior outcomes, not just cognitive ones. Varelas, Becker, Luster, and Wenzel (2002) explored the interaction between cognition and affective and social factors. They advance a multifaceted approach to motivation by showing that affective reactions are crucial for learning science. Echoing social constructivism, they view learning as a social process starting with transactions between student and teacher, as well as among students. Kaya and Ebenezer (2007) investigated the effect of long-term, authentic research projects on affective dispositions in science. They found that students developed better attitudes toward science itself, as well as more self-confidence, through such activities. Again, motivation, as well as inquiry-based instruction, requires attention to a complex interplay of variables in the classroom. Not only is inquiry potentially effective for academic achievement, but it may also have a positive impact on a student's well-being, when properly implemented.

Butler (2009) explored three main approaches to motivation: realness, rigor, and relevance. These reflect the precepts of culturally relevant teaching: critique, competence, and relevance (Ladson-Billings, 1995). For teachers in a diverse context, the framework

of culturally relevant pedagogy expands this framework to address these factors. Ladson-Billings (1995) proposed three principles of CRP:

1. Students must choose to experience academic success.
2. Students must develop and/or maintain cultural competence, which is a vehicle for learning.
3. Students must develop a critical consciousness through which they challenge the status quo of the current social order to become active citizens.

This approach also invokes an ethic of care in addition to an ethic of critique towards science education that is morally transformative (Shapiro & Stepkovitch, 1995). In a qualitative case study, Kelly-Jackson and Jackson (2011) found that cultural relevance provided an effective pedagogy to meet the social and academic needs of elementary and middle school children of color. Teacher beliefs and teaching practices were consistent with three major tenets of culturally relevant pedagogy: conceptions of self and students; social relations, and perceptions of knowledge (Ladson-Billings, 1995). They identify the motivation model of Oyserman and Destin (2010), which echoes Ladson-Billings' (1995) call for cultural competence. Goldenberg (2013) suggested that we re-think non-White students'cultural capital by innovating instructional strategies to better engage them in the classroom. Dimick (2012) asserted that student capital can be leveraged not only for their own achievement, but for academic, social, and political empowerment and politically. Such transformative education can then foster the re-envisioning of science education as a force for social justice, including environmental justice.

Science and Science Education as Sociopolitical Arenas

As science education expanded its vision, Hodson (2003) recommended transforming science-technology-society (STS) curricula into a politicized curriculum that reflected a more authentic approach to science. Akin to STEM curricula, STS curricula should, in his view, consider political interests and social values to prepare them for sociopolitical action. He purported that environmental problems are a social construct, to be identified and solved by confronting social conditions and societal practices. However, the realization of this view depends on science instruction as enacted by science teachers.

Conceptual discussions about a sociopolitical approach to science education continued. In light of education about climate change, Schneider, Krajcik, Marx, and Soloway (2002) cited motivation towards action and the accumulation of sufficient knowledge as assumptions for student empowerment. Therefore, science education could become a means of empowering citizens, enabling them to make personal decisions on matters such as climate change, as well as act as participants in social change regarding such global issues. The development of critical thinking, not just literacy, is essential for students to be able to understand the social issues we face, and the ability to make intelligent decisions about them (Abrami, Bernard, Borokhovski, Waddington, Wade & Person, 2014).

Benzce and Carter (2011) built on Hodson's (2003) call for politicization of the curriculum, and reframed student empowerment as a form of social justice. Their highly critical work stressed the link between a hyper-economized society, environmental degradation, and oppression. In their view, science education (which is currently

characterized by the STEM approach) has become a means to plug students into a globalized society obsessed with capitalism. They suggest teaching activism in science class to question the status quo. These authors did not suggest how exactly science teachers could accomplish this goal outside of providing theoretical frameworks. Howe and Berv (as cited in Jorgenson, 2014) cite the disconnect between teaching model and practice. The gap between theory and practice is common, especially in light of constructivism, where congruence between epistemology and pedagogy continues to be missing (Ennis, 2011). While epistemological constructivism posits that we construct truths but not their relationships, pedagogical constructivism asserts that students learn best when they construct their own answers the problems and questions (Ennis, 2011). Bazzul (2013) applies Ranciere's (2011) notion of radical equality to not only empower students, but also to emancipate them. He proposes connecting pedagogy with politics in science education by introducing value-laden discourses in which the situated voices of the learners come forth (p. 250).

Science for Environmental Justice

If science teachers are to begin motivating students through environmental justice, they have to learn how to do teach through such a lens. Scholars such as Steele (2011) began to investigate teachers' abilities and attitudes towards this approach. In a study of secondary science teachers charged with including environmental education (i.e. ecology and environmental science) in their curricula, she elucidated six discrete findings. Most germane to the current study is Steele's (2011) finding that teachers tend to teach science as politically neutral, thanks to a sacred body of knowledge to be transmitted to students, rather than recognizing the discipline as value-laden (Hart, 2003). Politicizing the

problem, Barton (2002) cited environmental racism and a hierarchy based on scientific literacy that marginalizes those without scientific knowledge. Therefore, Laughter and Adams (2012) argued that we teach science in a way that sustains a myth that science represents unbiased knowledge, although culturally relevant approaches are making progress in helping not only to engage students in new ways, but offering teachers new ways to view science and science education. To this point Robertshaw and Campbell (2013) explored the potential impact of aligning epistemology and pedagogy in per-service teachers.

Science teacher epistemology can be problematic because they have maintained a tradition of enculturating students into a traditional form of science, signaling a hegemony to be critiqued and perhaps dismantled (Hodson, 1999). Von Secker (2002) found that inquiry does improve student achievement in science, but the efficacy of inquiry-based teaching is context-dependent. Indeed, she found that it could *widen* achievement gaps when she examined gender, minority status, and socioeconomic status. Lee, Buxton, Lewis, and LeRoy (2006) uncovered a similar disparity between inquiry and diversity among elementary school students. Thus, research shows that inquiry may motivate students, but it may promote inequity, rather than eliminating it.

Science teachers can perpetuate the enculturation of students into science by relying on science textbooks rather than on student-centered strategies (Steele, 2010). By perpetuating the so-called tradition of science (including the alleged notion that all students can learn science equally), science teachers rely more heavily on the predictability of textbooks, and essentially deter meaningful change in science teaching. Gayford (2002) confirmed the reluctance of science teachers to address socio-political (or

economic) implications and applications of science, sidestepping controversies, and effectively alienating and disempowering students. However, Toolin and White (2013) presented social justice-themed, project-based strategies. They showed that teachers could design inquiries that lead students in investigations of social issues through explorations aligned with science standards.

On the other hand, Jorgenson (2014) connected the interests of science teachers who participated in "green pedagogies" to their childhood experiences. Those teachers felt comfortable addressing the moral, social, and political aspects of environmental issues. However, they did not scrutinize the vocational and economic stress of their STEM-oriented practices, which at least led them to teach in traditional ways (e.g. hands-on science). Ladson-Billings (1995) recognized exemplary teachers who were committed to teaching and learning with higher purpose. Such teachers believe that all the students are capable of academic success, view pedagogy as a dynamic, evolving art, and saw themselves as members of the community, with their work as a way to give back to the community. In their case study on urban, high-poverty, minority students, Basu and Calabrese Barton (2007) found that students developed a sustained interest in science when the activities supported a sense of agency for enacting their views on the purpose of science, especially if science could be used to improve their lives.

Toolin and White (2013) supported the ability of science educators to help students analyze their beliefs and practices, as well as their ability to empower students to take part in creating a more inclusive, just, and peaceful society. They modeled lesson designs based on project-based learning as described by Krajcik, Czerniak, and Berger (2002). While this pedagogy shares many of the tenets of problem-based learning (Lu,

Bridges, & Hmelo-Silver, as cited in Sawyer, 2014), the key facets include an interdisciplinary approach, differentiation, real-world (especially local) issues, student choice, and social justice. Such lessons are learner-centered and collaborative. Problem- and project-based learning circle back to sociopolitical aims of science education in the form of socioscientific issues (SSI), which become the linchpin of a justice-based environmental science curriculum.

Sadler (2004) defined SSI as controversial social issues with conceptual and/or procedural links to science itself. Sadler (2011) reconciled the college-and-career-readiness agenda with the need for engaged citizenship, citing their interdependence. Alsop and Watts (2000) showed that physics students' inquiry into radiation and radioactivity led to "informed excitement and animated understanding" (p. 138). The relevance of the topic to the students' lives engaged them cognitively as well as affectively. Placing the subject matter in a relevant context revealed the students' concern. Zeidler, Applebaum, and Sadler (2011) presented a novel framework for an SSI curriculum that they described as "transformative" because students discovered the scientific concepts as they emerged from the socioscientific issues. More transformative, however, was the reorganization of norms that took place thanks to social discourse that includes challenging core beliefs and misconceptions. The SSI approach can evolve to include activism, as this critical pedagogy fosters awareness when students explore pressing issues such as climate change (Bader & LaBerge, 2011).

Therefore, there is the potential to infuse an environmental science curriculum with environmental justice. Blanchet-Cohen (2008) developed a stepwise framework to describe a student's development into environmental activism: connectedness, engaging

with the environment, questioning, belief in capacity, taking a stance, and strategic action. However, it is crucial to recall Feinstein and Kirchgasler's (2015) analysis of the NGSS. In their eyes, the standards' technocentric approach to applying scientific knowledge to solve environmental problems does not include guidelines on addressing the ethical or political challenges that arise when we question equality and justice.

Theoretical Framework

Throughout my life, I have participated in environmentalist activities and practiced science with the societal implications and applications of research in mind. I am comfortable invoking my values to address the moral, social, and political aspects of environmental issues (Jorgenson, 2014). Furthermore, like Gayford (2002), I recognize the reluctance of science teachers to address the socio-political and economic implications and applications of science. Science teachers' tendency to side-step controversies because of their own lack of understanding of the appropriateness of addressing these concerns, and their lack of preparation to help students do so alienates and disempowers students (Gayford, 2002). I perceive a mutualism in pragmatism and transformation. As a scientist, teacher, and educational leader, I value emancipation and empowerment of all people towards solutions that improve the conditions of the environment, society, and individual lives.

First and foremost, the research is framed by moral transformative leadership (Dantley & Tillman, 2010). Through this lens, I can conduct research as a means to advocate for democracy and equity, and to advance an agenda that promotes environmental justice. This perspective enables me to invoke the anti-oppressive framework of Kumashiro (2000), which includes education of the other (including the

privileged and the marginalized), education about the other, and education that seeks simultaneously to effect change in students and society.

Transformational teaching theory will serve as the pedagogy that transforms students' lives within the context of this research (Boyd, 2009). Theory connects emotional intelligence and transformational leadership to the praxis of teaching. Not only does this transformational approach support effective pedagogy in practice, but it also fosters leadership. Boyd (2009) evokes Bass' (1990) principles of transformational leadership: idealized influence, inspirational motivation, intellectual stimulation, and individual consideration. With this framework serving as my theories in use, I can unite authentically the spheres of my practice as an environmentalist, science educator, teacher of children, and educational leader (Argyris & Schon, 1974).

With a scientific background, I enact these four roles through a mixed pragmatic-participatory worldview. The pragmatic worldview is often associated with mixed methods and other interventionist research strategies (Creswell & Plano Clark, 2010; Venkatesh, Brown, & Bala, 2013). In addition to the problem-centered, applied sensibility of pragmatism, I contend that the genuine application of research of any kind is to empower people, whether researchers or participants, to effect change. Therefore, a participatory worldview complements a pragmatic worldview. Honoring the tradition of mixed methods research; the transformative-emancipatory approach of Mertens (2010) permeates my research design, with its over-arching and recursive premise of environmental justice, as an all-encompassing form of social justice. As pragmatism envelopes participation, so does the quantitative strand of the research envelop the qualitative strand.

This study also relies on sociocultural constructivism. Vygotsky (1978) contended that because learning is a social process, individuals construct their knowledge, rather than having it transferred to them. Motivating students cannot be forced, but rather influenced. A constructivist pedagogy recognizes the need for students to interact and then internalize their thoughts to develop understandings (Vygotsky, 1978). Thayer-Bacon (2000) emphasizes working *with* students as opposed to intervening on him or her. Therefore, teaching as a facilitator in all senses and functions of the role would help students question their learning, as well as the world around them (Abrami, et al., 2014). However, Facione (1990) recommends the development of both critical thinking skills and dispositions. The alignment of cognitive and affective domains suits an environmental justice-based agenda. The encompassing and kaleidoscopic framework that unites the cognitive with the affective, science with science education, and environmentalism and environmental justice leads me to stop just short of radical constructivism.

Von Glasersfeld (1996) posited that since constructivism implies that knowledge is changed, the teacher's intended knowledge is not the only possible knowledge. While experiential learning is paramount, the context of the learner is ever-changing and unique to him or her. The same logic applies to this study, in which students will tell (and retell) the stories of their experiences in their environmental science class. Indeed, Bazzul (2013) asserts that as students develop their own understandings, they are emancipated from the notion that science education involves the transmission of knowledge. That liberation can expand to a radical form of equality as described by Ranciere (1991), through participation in their environmental science class as well as in this research.

Like the evolutionary theory that undergirded my training as a scientist, these sociopolitical theories are framed by change. Learning promotes individual change, and leadership, when steeped in learning, promotes learning en masse, whether it is in the classroom or among colleagues. Congruence among my theories-in-use will buttress the research, as well as my practice. The research integrated these theories, which echo Theoharis's (2007) theory of educational leadership for social justice. My theoretical framework extends both his theory and Dimick's (2012) theory in that I ultimately seek to leverage environmental justice as a democratizing and inspiring force for students, colleagues, and community.

Conclusion

This literature review revealed the shortcomings in the evolution of science education since the development of the NGSS. With a neoliberal focus on "Science for All," inquiry-based teaching and STEM-related approaches have become the guiding force for science instruction. The literature provided contentious evidence for using inquiry in the classroom, especially among lower track or other disadvantaged students. Furthermore, goals of citizenry and empowerment have been forsaken in light of career and college planning. Disconnection from the natural world as represented in environmental education has left America's students disengaged with environmental situations. Furthermore, student motivation has been specious or spurious due to the combined effects of factors that engage any given student. This void is further exacerbated by the lack of social justice education in American schools. The current study expands environmental science to consider environmental justice, which leads to questions about the post-positivist nature of science itself and its application. This study's

research questions were designed address the potential for environmental justice to motivate environmental science students, thereby providing insight into the philosophical issues of science and science education, in addition to the pragmatism of empowering students through this lens. The mixed methods approach in this study led to the collection of quantitative and qualitative data that answered the research questions and contributed to filling the gap in the available literature.

High School Environmental Science

Environmental Science is the third course in a lower-track sequence of lab-based sciences required for graduation. Usually, it is co-taught by a special education teacher. According to the syllabus, the course follows a problem-based approach to help students develop "the knowledge, dispositions, competencies, and environmentally responsible behaviors that signal environmental literacy" (BHPRSD, 2016). Revised by the three district Environmental Science teachers working in a professional learning community, the course content revolves around a systems-approach to studying the environment, which includes human society. The inquiry-based pedagogy is overtly interdisciplinary despite a focus on STEM education, and as of 2016, the curriculum was aligned with the Next Generation Science Standards.

The curriculum offers enough freedom for teachers to introduce current events. These topics are identified by individual teachers as they develop their lesson plans on a weekly basis. Thus, while the units are set up as guidelines to address socioscientific issues including biodiversity, natural resource management, pollution, and climate change, Environmental Science teachers are encouraged to include topics of most immediate relevance, such as pipeline construction and extreme weather events. The

teachers contend that such issues help students "improve their literacy and numeracy skills, in addition to practice of modern scientists" (BHPRSD, 2016).

Therefore, the curriculum is primed for a socioscientific approach, and the dispositions to be operationalized align with environmental justice, the social movement that "promotes the fair and equitable treatment of all people with the respect to environmental policy and practice, regardless of their income, race or ethnicity" (Withgott, 2011, p. 26). Environmental justice advocates seek to provide all people with "protection from environmental and health hazards and equal access to the decision-making process to have a healthy environment in which to live, learn, and work" (EPA, 2015).

The curriculum was developed with ecocentric dispositions in mind. The curriculum extends the interconnectedness and interdependence of natural systems to include social systems. Therefore, the goals of the course are aligned with the abilities cultivated through environmental literacy as described by Hollweg et al. (as cited in BHPRSD, 2016). By studying Environmental Science, students will be able to make informed decisions concerning the environment; be willing to act on these decisions to improve the well-being of other individuals, societies, and the global environment; and participate in civic life.

Chapter 3

Methodology

The purpose of this design-based mixed methods study was to explore changes in the dispositions of students in high school environmental science classes in New Jersey as I attempted to motivate and empower them through lessons framed by environmental justice. A social movement that "promotes the fair and equitable treatment of all people with the respect to environmental policy and practice, regardless of their income, race or ethnicity" (Withgott, 2011, p. 26), advocates of environmental justice seek to provide "protection from environmental and health hazards and equal access to the decision-making process to have a healthy environment in which to live, learn, and work" (EPA, 2015). These lessons were developed in alignment with the Next Generation Science Standards and undergirded by environmental justice. Per Creswell and Plano Clark (2010), data collection in this embedded study began and ended with a quantitative strand of inquiry, which consisted of a survey administered at the beginning of the school year and again at the end of the introductory unit of the course (see figure 1). The survey was comprised of items that gauged students' dispositions about science education, and the environmental issues they would learn about in Environmental Science. The findings of the initial survey informed the intervention (i.e. the lessons framed by environmental justice meant to motivate students). The same survey, administered at the end of the curricular unit, provided data to provide a basis of comparison, to track general changes in student dispositions. The quantitative strand also helped me identify potential participants for the qualitative strand of the study.

The embedded qualitative strategy was influenced by narrative inquiry, as I explored the stories of individual students through their time spent studying environmental science (Clandinin & Connelly, 2000). During semi-structured interviews, students were prompted by their own assignments. Qualitative data sources also included journals maintained by students, which gave more introverted students a voice (Windschitl, 2002). I maintained a journal of my own, to enrich descriptions of the students' experiences (Glesne & Peshkin, 1992). Administering the same survey to all students allowed me to track changes in dispositions of all students, including those who participated in the qualitative phase. This study answered the following questions:

1. How do student dispositions towards science in society change as a result of studying environmental science?
2. How do student dispositions towards environmental justice change as a result of studying environmental science?
3. What insights emerge from the stories told by high school students about their experiences in Environmental Science when taught through the lens of environmental justice?
4. How can these findings be used to improve the overall learning experiences of high school environmental science students in an era of the Next Generation Science Standards?

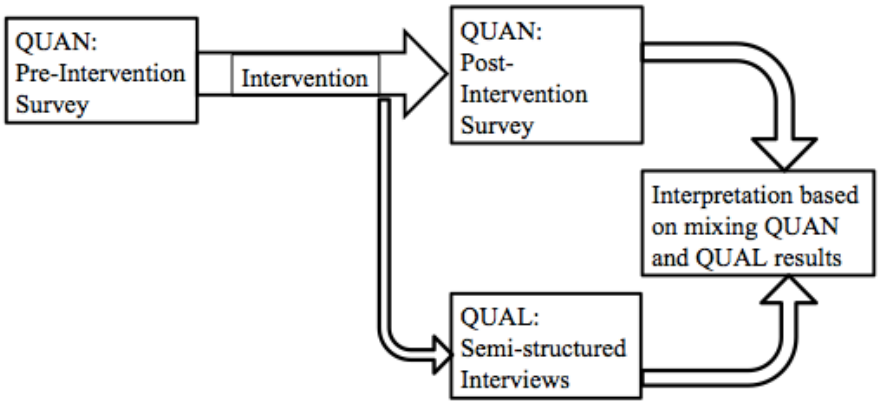

Figure 1. Research design

Assumptions of and Rationale for Mixed Methods Research

An embedded mixed methods research design was used for this study because student motivation is a complex phenomenon that should be explored by an integrative, iterative approach (Creswell & Plano Clark, 2010). Mixed methods approaches allow researchers to explore emergent insights and gain an in-depth understanding of a phenomenon throughout the research experience (Jang, McDougall, Pollon, Herbert, & Russell, 2008). In a mixed methods design, the data collected during multiple strands of inquiry inform each other at some point during the study, allowing for more thorough data collection, analysis, and/or interpretation. These two distinct strands merge at any point or points in the course of the study (Leech & Onwuegbuzie, 2007). Through a quantitative analysis of literature on science education research, Devetak, Glazar, and Vogrinc (2010) found that mixed methods research emerged as an established research design in science education because qualitative methods complement quantitative methods, especially if the methods were mixed. The triangulation of data collected through the differing phases allows for deeper investigation into phenomena surrounding

science teaching and learning, especially when the research is involved in his or her own study.

The embedded mixed methods design provides several advantages towards answering research questions (Creswell & Plano Clark, 2010). The intent was to explore the changes in dispositions of students overall, but because I also wanted the students' voices to be heard, a single data set (either qualitative or quantitative alone) was not sufficient. Because each of the research questions required different types of data, different methodological approaches were necessary. Therefore, the qualitative arm was embedded within the quantitative arm. It is considered a design-based, embedded design because the quantitative arm informed the intervention, which was evaluated initially through qualitative methods, and secondarily through quantitative methods. The second survey offered overall insight into the effectiveness of the intervention. Embedding the qualitative component within the quantitative component allowed for the examination of an intervention, which in this case is lesson design (Creswell & Plano Clark, 2010).

Mixed methods research was appropriate for this study because of its adherence to pragmatism. The integrative nature of a mixed methods design essentially complements design-based research, which is interventionist and seeks to produce dynamic, usable knowledge that informs real-world practice (Akilli, 2008). Greene, Caracelli, and Graham (1989) valued the differences in philosophical paradigms that can drive a researcher's methodology, and elucidated five purposes for selecting a mixed methods design: triangulation, complementarity, development, initiation, expansion (Greene, Caracelli, & Graham, 1989). In particular, the quantitative phase helped to develop the intervention. These aims drive the pragmatic nature of design-based research while increasing validity

(through triangulation) and meaningfulness of the inquiry as well as its breadth, depth, and scope. Thus, it is ideal for classroom-based research in education. Edelson (2002) declares that design based research offers opportunities to develop unique knowledge that can be applied directly to discrete situations as well as to the direct improvement of education.

I also subscribe to a transformative-advocacy paradigm that seeks to empower participants (i.e. the students). Thus, the research aligns with the transformative mixed methods approach of Mertens (2010), which addresses concerns of social justice and allows the research to question power structures that promote social inequities. Mixed methods allow researchers to juxtapose paradigms to gain greater insights into the phenomena they are studying. A dialectical stance emerges, promoting interaction between strands of research (Mertens, 2010). In addition, when a researcher is directly involved in the setting under investigation, qualitative methods lead to richer details than quantitative data can provide alone, and reveal important nuances. Thus, qualitative research "offers perspective on a situation...and reflects the researcher's ability to illustrate or describe the corresponding phenomenon" (Devetak, Glazar, & Vogrinc, 2010).

Design-Based research. Wang and Hannafin (2005) called for the use of multiple methods in collecting data for design experiments. A design-based approach is valuable for a teacher-researcher because the interventions can be evaluated with diverse techniques, in a variety of combinations and in authentic contexts such as the classroom (Anderson & Shattuck, 2012; Bergroth-Koskinen & Sepalla, 2012). Driven by a need recognized by the practitioner, design-based research is ideal because the practitioner-

researcher can then rely on the passion and expertise required to undertake the challenge of developing and supporting, and evaluating an intervention – all while continuing to practice (Anderson & Shattuck, 2012). Herrington, McKenney, Reeves, and Oliver (2007) consider design-based research socially conscious, for the problems that practitioners themselves identify form the foundation of research and development, and therefore of innovation and educational reform. Furthermore, design-based research "generates an artifact" that enables teachers to teach more intelligently, leveraging their competence, beliefs, intentions, and attitudes (Juuti & Lavonen, 2006, p. 62).

Wang and Hannafin (2005) outlined nine principles of design-based research that clarify what Edelson (2002) called the "messiness" of the paradigm, and assisted me in the design of this study:

1. Support design with research from the outset
2. Set practical goals for theory development and develop an initial plan
3. Conduct research in representative real-world settings
4. Collaborate closely with participants
5. Implement research methods systematically and purposefully
6. Analyze data immediately, continuously, and retrospectively
7. Refine designs continually
8. Document contextual influences with design principles
9. Validate the generalizability of the design

This framework unites and integrates research with action. Furthermore, it "generates a practical, credible, and contextual plan" for inquiry (Wang & Hannafin, 2005, p. 15).

The depth of purpose plumbed by a design-based, mixed methods approach honors the many forms of constructivism described by Geelan (1997a). In actuality, this study's focus on a novel lens for environmental science reflects the manner in which knowledge can be constructed: for personal or social reasons, for context or critique, towards objectivism or relativism. Science has a role in society, and Geelan's (1997a) epistemological anarchy supports the pragmatic, transformative, and emancipatory intentions of both science education and educational research. Design-based research features both theoretical and practical goals as it aims to bring about changes in instructional praxis without isolating teaching and learning from its immediate context (Barab & Squire, 2004; Bergroth-Koskinen & Sepalla, 2012).

The intervention took the form of lesson design, as influenced by the initial survey results. I developed lessons aligned not only with the NGSS, but also with the learning targets presented in the curriculum (BHPRSD, 2016). However, I designed lessons with socioscientific issues in mind, as well as the needs of the learners. I was prepared to consult with the following critical friends: my co-teacher (a special education teacher) and colleagues in the English and social studies departments, who share a similar commitment to interdisciplinary and social justice teaching. My professional learning community consisted of the other two Environmental Science Teachers in the district; we maintained contact through email, semi-annual meetings, and a Google Drive. Finally, I consulted with an extensive professional learning network through email and Twitter. The instructional strategies would be tailored to the needs of the students, who would be welcome to express preferences beyond what I could assess.

Clandinin and Connelly (2000) offered a parallel context for social science research through narrative inquiry based on Schwab's (1960) article "What Do Scientists Do?" Through a mixed-methods design, I was able to practice the scientific logic and methodology of my training in the biological sciences during the quantitative phase, and rely on my training as a writer through the qualitative phase (Creswell & Plano Clark, 2010). However, this balance also enabled me to temper a scientific mindset in favor of understanding situations that involve authentic learning in order to produce actionable knowledge that strives to "change discriminatory systems and/or their impact on the lives of others for the better" (Kinsler, 2010, p. 184).

Narrative inquiry. The qualitative phase of the study was influenced by narrative inquiry, which emphasizes telling and re-telling stories (Clandinin & Connelly, 2000). The use of narrative inquiry allowed me to prioritize the voice of the students, rather than my own.

Clandinin and Connelly (2000) cited John Dewey as an inspiration for the development of narrative inquiry because of his adherence to experience and continuity. In essence, narrative inquiry is a constructivist approaches that reflects experiential learning and is fitting for research in science education, which follows the same modus operandi (Hunter, 2009). Student narratives helped to capture the three-dimensional space of their learning environment: temporality, the personal-social dimension, and place (Clandinin & Connelly, 2000), thereby capturing the complex and dynamic nature of motivation and engagement that reveals dispositions. Through this strategy, I bridged the gap between first- and second-person research and practice (Kinsler, 2010). Juuti and Lavonen (2006) link design-based research to narrative inquiry in their discussion of

design narratives, which describe the process, artifacts, and rendered knowledge relevant to the study.

Participants

Context

The research was conducted at Timber Creek Regional High School, located in Erial, NJ, a suburb of Philadelphia. It is one of three high schools in the Black Horse Pike Regional School District. There are approximately 1400 students enrolled, with a majority of White students (55.6%). Thirty-four percent of the students are Black, 5% are Hispanic, 4.6% are Asian, 0.7% are American Indian. Thirty-one percent of the students are enrolled in the free and reduced lunch program and 12.6% of the students are enrolled in special education services. (NJ DOE, 2015). It is culturally and socioeconomically diverse. This site is appropriate because the research will be conducted where I teach the students, which include the classroom, the computer labs, library-media center, and the rain garden that serves as an outdoor classroom. Administering the survey suited the design-based nature of the study by allowing the students to reflect on their dispositions in their learning environment. Furthermore, students were encouraged to select locations within the overall setting to validate their participation, thereby attending to the spatial dimension that contributes to the three-dimensional space of narrative inquiry (Clandinin & Connelly, 2000).

Participants

The participants included students from three sections of environmental science students. These students are mostly juniors, with some students retained in their sophomore year, and others repeating the course as seniors or finally taking this course,

which is the third in a lower-track sequence of lab-based sciences required for graduation. A total of 60 students were in three sections of the course that reflect the demographic breakdown of the school, with various students having IEPs or 504 plans. A majority of the students fit San Martin and Calabrese's (2011) description of students in alternative schools "who seemingly lack successful educational experiences, are at-risk of dropping out, or are dissatisfied with the traditional school setting" (p. 3).

Sampling

Visual inspection and statistical analysis of the survey data informed critical case sampling to highlight potentially participants for the qualitative arm of the study (Creswell & Plano Clark, 2010). Resulting criteria were used to approach these candidate participants based on their survey responses. I recruited additional participants via snowball sampling, as willing participants suggested other students who were willing to participate (Patton, 2002).

I welcomed any environmental science students who wished to lend their voices to this study, until data collection reached a saturation point (Seidman, 2003). The sample for the narrative inquiry reflected that which is needed to sufficiently contribute to the narrative. I wanted to capture as wide a breadth of experiences of this classroom as possible, with students representing a variety of dispositions, as uncovered by the initial quantitative survey. Students who were willing to participate were accepted until a complete story could be told, providing a rich description of the experiences of the classes at large (Riessman, 2007).

Data Collection Methods

Quantitative Data

The purpose of surveying is to collect information about students' dispositions in a measureable way (Fowler, 1993). Even though quantitative research is meant to be objective, a survey can provide numerical data that can be analyzed statistically in a reliable and verifiable manner (Devetak, Glazar, & Vogrinc, 2009). The relative ease of administering a survey afforded the quick opportunity to collect this data to inform the intervention, as well as to identify potential participants for the qualitative phase of the research (Creswell, 2014). The data were collected in a consistent, numerical fashion under the assumption that the students were responding honestly, thoughtfully, and reflectively (Fink, 1993; Locklear, 2012).

The goal of the quantitative arm was to detect trends in student dispositions at the beginning and end of the study, and to provide data to inform the intervention (i.e. lesson design). I obtained approval through the Rowan University Institutional Review Board on Human Subjects (IRB). On a voluntary basis, I piloted the survey with the preceding Environmental Science students to assure the language of items and time required for completion, thereby contributing to construct validity (Fink, 2013). Piloting allowed for the opportunity to make revisions before administering the survey to the participants. These students were not eligible for participation in the study.

Marking the beginning of the study with introducing the research and providing informed consent forms, I administered the survey on a voluntary basis to the Physical Science students whom I identified as enrolled in Environmental Science for the upcoming September. Thus, I intended to control for variables such as tension arising

from the new school year and immediate preconceptions of the course. Students who did not return to school or who did not enroll in the course were excused from the research and their paperwork destroyed.

I administered the survey once again at the end of the introductory curricular unit, which included the lessons designed as part of the intervention, as informed by the survey data. This unit lasted approximately seven weeks following the beginning of the school year. Again, participation in the survey phase was voluntary. The hypothesis concerned the change in student dispositions towards science and environmental justice as a result of studying environmental science through the lens of environmental justice. Thus, environmental justice as thematic approach to teaching environmental science is the independent variable, and the change in student dispositions is the dependent variable.

Qualitative Data

Semi-Structured interviews. The purpose of the interviews, conducted following the introductory unit of the course, was to explore the dispositions of individual students as they studied environmental science through the lens of environmental justice. Once participants for the qualitative strand were identified, and recruited as volunteers, they were interviewed in a school setting that best fit their comfort level, including the classroom itself, the library-media center, and the outdoor classroom. The timing of the interview also suited their needs. I followed the interview guide approach, which elicits participants' worldviews (Rossman & Rallis, 2011; Turner, 2010). Although I developed categories and topics to explore in alignment with the research questions, I remained open to pursuing topics that the students brought up. In this way, the conversation was balanced in favor of the student-participants, and unfolded as they saw fit (Rossman &

Rallis, 2011). Thus, this method maintained flexibility despite the composition of the interview questions (Johnson, 2010). The interviews also occurred at the end of the curricular unit, but with time to ensure that the student participants had a chance to complete the post-survey before their interviews.

Journaling. Students who wished to participate but were reluctant to meet for face-to-face interviews were offered the opportunity to keep reflective journals. Students were offered prompts comparable to the questions developed for interviews. I reviewed journals after each entry to maintain the contemporaneous nature of the experience, and to provide prompts in alignment with the interview protocol (Giraud, 1999). I made every effort to ensure that my feedback was not evaluative (Giraud, 1999).

I maintained my own researcher's journal, which served several purposes. It served as a means to track ideas and thoughts to prompt reflection and maintain focus on the research (Merriam, 1998). I made every effort to record accurate descriptions that were not judgmental, yet helped me (and the participants) re-visualize the events in the classroom (Glesne, 2006). I also recorded ideas that would prompt further questions in interviews (Bowen, 2009).

Instrumentation

Survey protocol. The survey, created on Google Forms, began with demographic data that allowed the students to describe themselves in terms of sex, age, race, and ethnicity. The survey (see Appendix A) was inspired by the Relevance of Science Education (ROSE) Project developed by Jenkins and Pell (2006) to explore students' own perspectives about the relevance of learning science. Through an affective approach, the project assumed that the views and perspectives of learners is a prerequisite for effective

teaching. Therefore, I contextualized the questionnaire's focus on student dispositions about their own connection to science learning, their personal ambitions, and the environment to create survey items.

While the ROSE survey measured student responses with a four-item Likert scale, the current study used a 10-point scale. Wittink and Bayer (2003) found that a continuum of a10-point scale offered more opportunity to detect changes in responses, and more explanatory power. The larger scale also offers more variation in responses, and therefore more opportunity to express opinions with more nuances, which students tend to prefer (Tucker-Seeley, 2008). The even-numbered scale also represents forced-choice questions, so that students could not take the "path of least resistance" by claiming uncertainty or ambivalence (Fink, 2013). The survey items reflected the following themes: what students wanted to learn about in environmental science, ambitions for their future, their perspectives of environmental challenges, and their opinion about science classes. Schreiner and Sjoberg (2004) address the validity of the ROSE survey in light of its use across cultures, and stress the subjectivity of a survey in contrast to administering a test with correct and incorrect answers. Schreiner and Sjoberg (2004) specifically advocate internal consistency (a form of reliability) by calculating Cronbach's alpha, which measures how well the survey items correlate with one another, and with the overall scores. At the end of the survey, students could indicate if they were willing to participate in the qualitative portion of the study, specified by the options to participate in an interview or keep a journal.

Interview protocol. The interview questions were developed in light of the research questions. Interviews were scheduled for 45 minutes. The eight interview

questions, which served as open-ended prompts, reflected the following themes: what students wanted to learn about in environmental science, ambitions for their future, their perspectives of environmental challenges, and their reflections on science classes (see Appendix B). These interview prompts were piloted with Environmental Science students at the end of the prior school year in informal settings to assess the potential for open-ended responses. I asked each student the same basic questions, making sure to collect data that addressed the research questions. Because I could not predict the stories that the students themselves would find worth telling, the questions resembled invitations for the students to tell stories that were meaningful for them (Trahar, 2009). Then, I shared my reflections in the form of follow-up questions to prompt more student expression.

Each student brought his or her class notebook to the interview. Each student maintained an organized, sequenced binder of notes and assignments for reflection and study; throughout the interview we could refer to specific pages of their notebooks. I audio-recorded the interviews on an iPad and transcribed them myself to proffer intimacy with the data (Merriam, 2009). I also maintained a researcher journal throughout the interviews, allowing me to gather further data (Creswell & Plano Clark, 2010).

Journal. Students who wanted to participate through journaling were allowed to choose the format with which they were comfortable. They could maintain a hard copy in their preferred type of notebook, or an electronic version (e.g. Microsoft Word document or Google Doc (Giraud, 1999).

For the researcher journal, I expanded my daily reflective teaching practice of taking notes on 3x5 index cards by elaborating on these notes after school each day in a composition book (Glesne, 2006; Merriam, 1998). My journal was meant to be more

descriptive than analytical, and the source of ideas for interventions (i.e. lesson designs) and data for interview questions. I recorded student comments and interactions, as well as observations about student-participants.

Data Analysis

After the initial survey, the quantitative data were prepared for analysis to get an overall picture of student dispositions, as well as to inform the intervention (i.e. lesson designs). The quantitative data also led to the sampling of students for the qualitative phase of the research. Survey data were "cleaned" by visual inspection for errors in self-reporting. Such data from students who answered the survey inattentively or carelessly were marked for omission (Creswell & Plano Clark, 2010; Meade & Craig, 2001). Next, I explored the data through visual inspection, in a search for trends and distributions, which were summarized in a codebook that captured the variables, their definitions, and the associated numerical data (Creswell & Plano Clark, 2010). Further exploration included the descriptive analysis of the data through the calculation of means, modes, and medians (Creswell & Plano Clark, 2010).

To prepare the qualitative data, the interview recordings were transcribed verbatim after each interview, and then summarized via analytical memo (Rubin & Rubin, 2012). In addition, the codebook was developed (Creswell & Plano Clark, 2010). It included codes to provide a basis for qualitative coding. Student journals were prepared in a similar fashion.

Quantitative Data

Through this quantitative analysis, I looked for an overall picture of student dispositions before and after the intervention. Analysis of quantitative data began with

visual inspection, a descriptive analysis via memo, and a check for trends and distribution (Creswell & Plano Clark, 2010). I used Microsoft Excel to calculate the medians as well as the means for the survey responses to look for general trends among responses; that is, the typical student's dispositions (Fink, 2013). I used a correlation analysis on the initial survey to look for preliminary relationships among dispositions (Peers, 2006). After each survey, I conducted a normal probability plot to look for outliers; results after the first survey were used to identify participants for the qualitative phase (Peers, 2006). A subsequent correlation analysis performed on the follow-up survey revealed relationships among survey items. A paired t-test looked for changes in student dispositions (Peers, 2006). I repeated this measure following the survey that is administered when the curricular unit including the intervention concluded. To depict the trends and distributions, initial survey data were presented in a table. Comparative data that incorporated an analysis of the follow-up survey responses were presented in a bar chart (Creswell & Plano Clark, 2010).

Qualitative Data

Interviews were transcribed verbatim after each interview, and then summarized via analytical memo (Rubin & Rubin, 2012). Influenced by narrative inquiry, I focused on the students' stories as a whole, to not only preserve the integrity of their experiences, but to shed light on the changes in their dispositions (Riessman, 2007). I reflected on the participants' stories in order to establish a connection to the classroom setting through their eyes, and coded the transcripts for further analysis (Saldaña, 2013). However, coding the data provided a means to analyze the content of the students' stories for changes in dispositions in light of their experiences in Environmental Science; to focus

on what they have said, rather than how they have said it (Elliott, 2005; Riessman, 1993). Coding is the iterative process of identifying words or phrases that provide discrete data in order to begin making sense of it, and later used to determine categories (Saldaña, 2013). Deconstructing the interviews through coding in order to make sense of the narratives, demonstrating a "vertical" form of analysis that reflects social constructivism, which undergirds this study (Hunter, 2009, p. 50).

I manually performed three cycles of coding. The first cycle was in vivo coding, which prioritizes and honors participant's voices, especially if they are youth that are marginalized. This method is appropriate for analysis because "coding with their actual words enhances and deepens an adult's understanding of their...worldviews" (Saldaña, 2013, p. 91). I identified and reflected on the initial codes that address the research questions for recurrence within and between transcripts to recognize similarities that would prompt a second cycle of coding.

The second cycle of coding continued with values coding, which is an affective method that reflects participant's "values, attitudes and beliefs, representing his or her perspectives or worldview (Saldaña, 2013). While Saldaña (2013) recognizes these three constructs as distinct, he also highlights the "interplay, influence, and affect between and among all three...that manifest themselves in thought, feeling, and action" (p. 111). Thus, they align with dispositions, which are a focus of the research questions.

Because coding is iterative and ongoing, I monitored the overlap of codes between the two cycles, whether they were "subsumed, relabeled, or dropped altogether" (Saldaña, 2013, p. 10). Codes were therefore sorted into themes based on categories and sub-categories, en route to the development of themes and concepts that highlighted the

students' stories (Saldaña, 2013). Saldaña (2013, p. 14) defined themes as "the outcome of coding, categorization, or analytic reflection, not something that is, in itself, coded." Bamberg (as cited in Saldaña, 2013) recommended that the study of narratives for structure and content is a proper starting point for analysis. Therefore, per the influence of narrative inquiry, I also considered a theme as a literary element, defined as a moral, life lesson, or significant insight per Saldaña (2013), thus blending the definition of themes. I followed the tradition of narrative inquiry by transitioning from field to text, and from field texts to research texts (Clandinin & Connelly, 2000). Finally, the interviews were coded based on Labov and Waletzky's (1967), structural model of narrative form, which presents the following narrative categories according to their functions:

- Abstract: Summary of the subject matter
- Orientiation: Information about the setting: time, place, situation, and participants
- Complicating action: What actually happened, what happened next
- Evaluation: What the events mean to the narrator
- Resolution: How it all ended
- Coda: Returns the perspective to the present

The outcome of the qualitative analysis was a series of impressionistic tales (van Maanen, 1990). Framed by the science lessons and augmented by my journal entries, the tales described the students' actions and their insights, creating an oral history that reflects the rich language of their stories (Leavy, 2011). Re-telling the stories in this way weaved what Geelan (1997b) calls a *narrative net* that captures the episodes in the classroom, as well as the feelings and thoughts of the students to create a grander picture

of teaching and learning as an act of ultimate reflection (Clandinin & Connelly, 2000). The narratives also became a "placeholder" for both quantitative and qualitative data to be collected and integrated, ultimately validating the mixed methods design (Creswell & Plano Clark, 2010, p. 95; Tashakkori & Creswell, 2007).

Mixing of the Data

A mixed methods study does not simply include the collection of multiple sets of data, but rather the integration of those data sets for a better understanding of the phenomenon (Creswell & Plano Clark, 2010). Mixing the data can occur at multiple points of data collection and/or analysis, taking advantage of the iterative nature of the research and potentially enhancing the research design as it proceeds (Teddlie & Tashakkori, 2006). I used several methods suggested by Jang, McDougall, Pollon, Herbert, and Russell (2008). I performed parallel integration for member checking and data transformation for comparison as I used the survey results to inform the interviews. I revisited the quantitative data at multiple times while analyzing qualitative data. Finally, case analysis provided the opportunity to create narratives of each student, which featured results from their surveys as well as input from their interviews. The students' stories generated insights that enabled a deeper, contextualized, and conceptual understanding of the students' own survey responses (Caracelli & Greene, 1993).

Data Quality and Rigor

To evaluate a mixed methods study, Creswell and Plano Clark (2010) suggested following standards for both quantitative and qualitative research, as well as mixed methodology itself. They echoed the recommendations of Hall, Ward, and Comer (1998): a mixed methods study "must use a type of design that matches the research question, a

theory that frames the study, and data collection that will lead to reliable and valid scores" (Creswell & Plano Clark, 2010, p. 267). In addition, the statistical test must be "appropriate and robust" while the study as a whole must "have accurate measures and be generalizable, valid and reliable, and replicable" (Creswell & Plano Clark, 2010, p. 267). In addition to criteria reflecting both the quantitative and qualitative research paradigms, the research should be explicit, transparent, relevant, and participatory (Bryman, Becker, & Sempik, 2008).

However, rigor in educational research does not represent standardized interventions, but "a broad variety of modalities, tools, and strategies for learning" (Ross, Morrison, & Lowther, 2011, p. 19). While those scholars focused on educational technology, I apply this logic to any classroom intervention, which may work with certain teachers or students with varying degrees of effectiveness. While environmental justice provided a pedagogical theme, the instructional strategies varied among lessons, to the benefit of individual students to varying degrees. However, an educational researcher must still strive for trustworthiness in data collection and analysis. It is important to note that I recognized that, like Trahar (2009), I was wary of students telling me what they might think I wanted to hear, in both phases of the research. I elaborate on this concern in the section on ethical considerations.

In light of the contrast between quantitative and qualitative research, Lincoln and Guba (1985) proclaimed that trustworthiness in research is essential. They described five criteria for quality: credibility, transferability, dependability, and confirmability. Transferability, or generalizibility, is not the goal of design-based research, which

focuses on local contexts (Barab & Squire, 2004). However, reliability and validity are still required.

Construct validity threatened the internal validity threat of the survey instrument (Teddlie & Tashakkori, 2009). I carefully constructed the survey to avoid double barrel questions, with wording the students would understand, and then piloted the survey to support validity (Fink, 2012). I performed a test of Cronbach's alpha on the piloted survey to validate the reliability of the survey instrument. Reliability addresses both the consistency of the results, the accuracy of the representation of the population under study, and the reproducibility of the results (Bashir, Afzal, & Azeem, 2008).

The mixed methods approach exposes the research to questions of validity (Creswell and Plano Clark, 2010). Feuer, Towne, and Shavelson (2002) suggest that the use of both quantitative and qualitative research tools can support stronger scientific inferences than the use of just one method. Triangulation, an essential component of the mixed method design, provided confirmability of the research, as quantitative and qualitative data will be mixed at interpretation (Creswell and Plano Clark, 2010). Thick descriptions of experience supplied by the students via narrative inquiry also supported credibility (Bulloughs & Pinnegar, 2001; Cochran-Smith & Lytle, 2009; Mishler, 1990). Furthermore, the reliance on student' voices were authenticated via member checking (Stringer, 2013). Data interpretation ensured validity via data integration, including parallel integration for member checking, data transformation for comparison, and data consolidation for emergent themes (Jang, McDougall, Pollon, Herbert, & Russell, 2008).

Some elemental practices addressed validity threats. I ensured credibility by prolonged engagement and member checking (Anfara, Brown, & Mangione, 2002). The

continuous interaction with students on a daily basis allowed them to revisit their interviews, which were triangulated with field notes. Dependability was ensured by peer examination (Anfara, Brown, & Mangione, 2002). In addition to a critical friend from Rowan, I also enlisted critical friends in the form of my course team members, who also teach Environmental Science in the district. This team includes my co-teacher.

This interventionist nature of design-based research leveraged teacher effectiveness and autonomy (Kinsler, 2010). Therefore, the study runs the risk of research bias because my personal beliefs and values are already reflected in the research design. The insights of critical friends and other professional colleagues will help clarify research bias (Creswell & Miller, 2000). Furthermore, the use of narratives subjects the research to threats of validity, as the telling and retelling of stories is essentially revisionist (Sandelowski, 1993). As a researcher, I must consider the inconsistencies and discrepancies in students' stories. I can accomplish this through member checking (i.e. member validation) to establish validity by allowing the students access to transcripts of the stories they have told (Sandelowski, 1993). This further empowers the students through continued participation in the research.

Gorard, Roberts, and Taylor (2004) considered design-based research to be messy because it is concerned with multiple variables, considers situations ethnographically, is flexible and participatory, and generates a plethora of data (which can be both quantitative and qualitative). Because design based research is conducted in a specific setting, generalizability is limited (Akilli, 1008). However, the findings do lend themselves to future theoretical analysis (Cobb, Confrey, diSessa, Lehrer, & Schauble, 2003). Barab and Squire (2004) contend that issues of trustworthiness and credibility in

design-based research align with those emerging from qualitative methodologies. Suffice to say, triangulation of data can promote validity in design-based studies, especially in mixed methods studies (The Design-Based Research Collective, 2003). In conclusion, the sophistication of design-based research (as a paradigm) and the thoroughness of mixed methods design (as a methodology) are supported by similar strategies to ensure rigor.

Researcher's Position

Practitioner inquiry blurs the boundaries between inquiry and practice, for the researcher is "working from the inside" (Cochran-Smith & Lytle, 2009, p. 41). As a science teacher, I am constantly pursuing and testing new approaches to teaching. As a natural scientist, I appreciate the assertions of Feuer, Towne, and Shavelson (2002) that educational research should develop into a stronger scientific community, beginning with individual researchers. While Herrington, McKenney, Reeves, and Oliver (2011) assert that design-based research is meant to be a collaborative effort, Steier (as cited in Geelan, 1997, p.558) noted the merger of teaching, learning, and researching as a form of "collaborative social learning." In essence, I merge the roles of designer/researcher and practitioner/teacher (Juuti & Lavonen, 2006). I honor Burkhardt and Schoenfeld's (2003) assertion that educational research needs to be more useful to practitioners as well as policymakers. Design based research also helps to bridge the gap between research and intervention (Akilli, 2008). Thus, this research revealed a bricolage of roles. The data collection methods provided congruence with this stance, as even the act of taking field notes helped to blend my roles as both a teacher and a researcher (Williamson, 1992).

Ethical Considerations

Guba and Lincoln (1994) stressed the centrality of ethics in the constructivist paradigm because the researcher must consider the participants' values. However, the personal interactions that develop because of the research process can become problematic. Indeed, this potential conflict is compounded by my role as teacher. I further recognize that favoritism could be an issue among students participating in the research, as well as those who have chosen not to participate. My stance as a teacher-researcher promotes concern for all of my students, and undergirds the study.

The primary ethical concern is the recruitment of my own students in the research. I recognized the "peril of easy access" to participants such students (Seidman, 2003, p. 41). I assured all students that participation was voluntary. In the ongoing pursuit of rapport with all students, I sought their trust, in an effort to minimize concerns of power and coercion by reinforcing the purpose of the research. To this end, I supplied each participant and their parents or guardians with an informed consent form so that they are cognizant of the scope and sequence of the study. Furthermore, snowball sampling created opportunities for additional students to participate in the research.

Participation was neither mandated nor rewarded. I made every effort to ensure that their decision to commit to, decline, or terminate participation at any time in no way was reflected in their grade or disciplinary record, in either a positive or negative way. I monitored those tensions that may arise as the qualitative arm unfolded. These ethical considerations also aligned with my commitment to the NJEA (2013) Code of Ethics, especially my commitment to my students and satisfy the constructivist stance of the "passionate participant" who facilitates change (Lincoln, 1991). I ensured that any

benefits that arose during data collection and analysis were shared with the class, so that no student enjoyed additional benefits, and no student was denied advantages that arise (NJEA, 2013).

I fully acknowledged the power dynamics inherent in the teacher-student relationship, akin to those of the researcher-participant relationship (Kvale, 2006). I pursued this study with their best interests in mind, mainly by empowering them by the very content and design of the research. Furthermore, I engaged the students as participants through dialogical pedagogy, in which "equally share[d] each other's knowledge and experiences, intentions and attitudes" (Kvale, 2006, p. 491). By bracketing my internal suppositions, I set aside my own assumptions and interpretations during data collection and analysis in order to defer to the students' stories (Gearing, 2004). Per Dunbar (as cited in Tillman, 2002), I placed students' knowledge at the center of the inquiry, and maintained contact with students as participants throughout the school year.

Before conducting the research, I obtained IRB approval through Rowan University, for which I received training in protecting human subjects, as well as approval from my district's board of education and my building principal. To ensure confidentiality, I used pseudonyms that were known to only me. The electronic files were password protected and hard copies of transcripts and student journals were stored in securely locked file cabinets.

Conclusion

This chapter elucidated the research design developed to address the research questions. The design-based, embedded mixed methods design began with quantitative

data to identify potential participants for the qualitative phase of the research. The data collection and analysis methods and instruments were described and rationalized. Issues of validity, credibility, and trustworthiness were addressed, as well as my role as the researcher and my ethical considerations. The following chapter presents findings of the study.

Chapter 4

Overview of Findings

This chapter presents an overview of the findings that emerged as a result of data collection and analysis to explore changes in the dispositions of students in high school environmental science classes in New Jersey as I attempted to empower them through lessons framed by sociopolitical action. These learning activities were grounded in environmental justice. Across the district, Environmental Science has been evolving into a problem-based course, with a pedagogical approach that leans towards a STEM-based approach. However, environmental justice may evoke an ethic of care that fosters the consciousness that elevates environmental literacy beyond general scientific literacy. In particular, environmental literacy considers dispositions with a foundation on concern for other people and other societies (Hollweg, et al., 2011). Such dispositions include attention to equity, a willingness to take action, personal responsibility.

This chapter supplies findings based on a survey that was administered before and after an introductory curricular unit that was framed by environmental justice. Therefore, the findings were synthesized through mixing quantitative and qualitative data. Furthermore, this chapter provides a transition to chapters five and six, which comprise manuscripts of scholarly articles.

The study sought to answer the following research questions:

1. How do student dispositions towards science in society change as a result of studying environmental science?
2. How do student dispositions towards environmental justice change as a result of studying environmental science?

3. What insights emerge from the stories told by high school students about their experiences in Environmental Science when taught through the lens of environmental justice?
4. How can these findings be used to improve the overall learning experiences of high school environmental science students in an era of the Next Generation Science Standards?

This chapter is organized to provide connections between the quantitative arm and qualitative arms of the study. A bar graph display results of statistical analysis (See Appendix C). A code book illustrates codes and themes that emerged throughout a dynamic process of data analysis (Anfara, Brown, & Mangione, 2002) (See Appendix D). The codebook highlights the qualitative findings by theme, with representative quotations from student interviews.

Description of the Participants

This year's Environmental Science students were divided among four sections. One section was co-taught by a special education teacher. Seventy students took the initial survey at the beginning of the school year; only 30 took the follow-up, despite numerous opportunities for students to take the survey during lessons, such as when assignments were completed ahead of time or when computers were available during collaborative lessons. While 24 students expressed interest in participating in the qualitative phase of the research, six students eventually committed to interviews (see Table 1). No students chose to participate through journaling.

Table 1

Participants' Demographic Profiles

Pseudonym	Andrew	Dayle	Hugo	Ivan	Katrina	Matthew
Sex	Male	Female	Male	Male	Female	Male
Race/Ethnicity	White	Latina	White	White	Black	White
Grade	11	11	11	12	12	11

Discussion of the Quantitative Findings

The findings of the initial survey informed the intervention, helped me identify potential participants for the qualitative strand of the study, and gauged overall changes in dispositions. After calculating the means and medians of the initial survey, I determined that the students would benefit from a socioscientific approach featuring lessons based in environmental justice. The frequency of student responses on the initial survey, shown in Appendix E, illustrate that student responses were slightly skewed to the positive side of agreement with most of the survey items. Taken as a whole, the students were not committed to an opinion about leaving problem-solving up to the "experts." Therefore, I decided that the idea of empowering citizens, in addition to students, would be an appropriate target for lesson design. Students overall were rather ambivalent in their perception of the role of science in society, nor declarative in matters of environmental justice. They did, however, value the role of morals in decision making. Therefore, I designed lessons targeted towards developing the dispositions that encourage an environmental ethic aligned with environmental justice.

Upon visual inspection of the data, there were no individual students whose responses identified them as potentially unique participants. Therefore, I sought out students out based on their willingness to participate further.

The third goal of the quantitative phase was to track changes in student dispositions as a result of studying environmental science. First, by the end of this curricular unit, there were no statistically significant changes in students' dispositions towards science in society. On the other hand, there were several significant changes in students' dispositions towards environmental justice. Throughout this unit, students significantly recognized the potential for environmental threats to affect them. In addition, they recognized a greater connection between environmental problems and social problems. Despite a strong agreement with the need to consider morals in environmental decision-making, the students as a whole agreed more strongly with this statement. The frequency of student responses on the final survey, shown in Appendix F, illustrate that changes in student dispositions overall. These data validate the development and implementation of lessons reflecting a sociopolitical approach, grounded in environmental justice (see Appendix G).

Discussion of the Qualitative Findings

Through the influence of narrative inquiry, I wrote analytical memos reflecting a brief biography of each student, and created a narrative net structured by the curricular unit plan. By using their own words, I made sense of the experiences of the students whom I interviewed. Furthermore, student's stories merged with quantitative data to prompt suggestions that can be used be used to improve the overall learning experiences

of high school environmental science students as we in an early era of begin the implementation of the Next Generation Science Standards.

Four key insights emerged from the stories told by high school students about their experiences in environmental science when taught through the lens of environmental justice. First, their notions of the environment diverged from a traditional nature-based perspective, which facilitated their view that the environment connects to society. Secondly, students came to see scientists as essential change agents, not just explorers and inventors.

Student Perceptions of the "Environment"

Students' perspectives of environment differ from their perspectives of nature, and have an abstracted notion of environmental problems and how they can be remedied. They describe the environment as something that is always changing, so an environment can be as manmade as a classroom to a park. With little overall connection to natural environments, they cite parks as environments that are peaceful places in which they can relax or play. In their eyes, the environment is comprised of commodities such as water, air, and lumber that provide them the stuff we need to sustain society. They view the environment as something that can be fixed, or left alone to heal. Their concerns are rooted in societal issues such as food deserts and water quality, which overlap with social problems such as poverty and discrimination. Students expressed some concern about deforestation, endangered species, and climate change. The current conflict over the Dakota Access Pipeline provides a connection between near and distant issues, as students became concerned about plans to build natural gas pipelines in New Jersey. Students could frame access to resources and suffering from pollution in terms of

environmental injustice. Correspondingly, they connected sociopolitical actions such as petitions and protests among the solutions to environmental problems. In conclusion, despite little personal connection to natural environments, students appreciate the interconnectedness and interrelatedness of the environment and society, and the impact problems in one domain has on the other.

The Role of Scientists in Society

Scientists, once seen as people who explore and discover natural phenomena, are now seen as people who identify problems in the so-called environment. The practice of science does not conclude with researching the cause of environmental problems. It continues with the development and proposal of solutions. Thus, scientists are central figures in society because, more often than not, students connected scientists to the policy-making process. Considering environmental justice requires fair treatment and meaningful involvement in the policy making process, students come to view scientists as change agents who can advocate for communities, especially marginalized or impoverished communities. According to students, scientists should be empowered with resources and through civic engagement to do work that ensures a clean environment for all citizens, who in turn should support scientific activities. Science students see themselves as scientists in light of their ability to monitor and identify environmental problems, such as water pollution, and provide solutions to food deserts. The students' view of scientists inextricably links the so-called environment with society and their own responsibility for the sustenance of both, despite traditional, direct, and personal interaction in nature.

Empowerment Through a Sociopolitical Approach

A sociopolitical approach to learning environmental science empowers students per the framework for social justice science education developed by Dimick (2012). Students revealed experiences that reflected all three dimensions: social, academic, and political.

Initially, students recognize the complexity of the way they are studying science. They notice changes in their values (often becoming ecocentric in their thinking) and able to transfer their knowledge of environmental challenges to other contexts, such as English and history class. They enjoy critical dialogues with each other and whole class discussions. They are engaged in authentic learning experiences, as opposed to being bored in other science classes that they considered devoid of relevance. In addition, they call for political action in solving environmental problems. Recognizing the purpose of learning science, they pity their unmotivated classmates, and consider attempts to motivate them for their own sake.

Thus, the students' motivation reflects social empowerment, which creates a contagious effect in the classroom. They routinely expressed determination and resolution in taking on environmental problems that will continue to intertwine with social problems as they grow into adulthood. They value collaboration and unity in addressing their community's needs. Finally, they espouse the need for science students to learn social skills in order to be socially and politically active.

Ultimately, their political empowerment reflects their civic engagement. The students strive for participation not only in class, but also in society, as they express concern for inequity and injustice, especially in light of marginalized and underserved

communities based on race, sexual identity, indigenousness, and socioeconomic status. They declared intentions to become informed of the status of environmental conditions and informing others. They see themselves joining or even coordinating protests, and signing or create petitions to confront business practices or political agendas that do not advance environmental protection. In summation, these three types of empowerment reinforce each other in a virtuous circle, fostering a democratic and participatory learning environment.

Preferred Approach to Science Education

As a curricular approach to science education, STEM was perceived as necessary but insufficient to motivate students. They value the role that technology and engineering play in science, especially in terms of solutions to environmental problems. However, they do not seem motivated by this approach. Students unenthusiastically discussed math, especially the creation and analysis of graphs. The students agree that STEM education is useful, but maintain that a sociopolitical approach is necessary to motivate students through a sense of purpose and empowerment, and awareness of the problems their generation faces. While they see value in integrating engineering and technology, they do not claim to be motivated by those disciplines, with the exception of using social media as part of their learning experiences.

STEM alone would not impress them as a unifying approach. They perceive science itself as an all-encompassing activity, especially in terms of a sociopolitical strategy that includes various disciplines including language arts and history. History, in particular, offers a sense of perspective and relevance that is missing from their prior science and engineering classes. A sociopolitical approach also requires a shift in

pedagogy preferred by students. Students favor science lessons devoted to socioscientific issues because, much like the aforementioned humanities, they allow students to explore their values and viewpoints, express themselves, and communicate with each other. Thus, a sociopolitical approach is more personal and social, especially when framed by the sense of fairness, equity, and inclusion that environmental justice promotes. Students are empowered by sociopolitical solutions because they can participate in those venues more readily. Ultimately, students compromised with a suggestion that the two approaches be incorporated in tandem.

Recommendations for Improving Learning Experiences

The findings from this study, as developed through the mixing of quantitative and qualitative data, can be used to improve the Next Generation Science Standards. Interrogating student narratives through case study analysis provided a means of exploring the experiences of the student interviewees. By mixing the data through parallel integration and data transformation, I could assist student participants in revisiting their survey data to explore specific changes in student dispositions.

The findings suggest that learning experiences for high school environmental students can be improved by a focus on socioscientific issues. Including such course content is not only motivating but it is also empowering. Sociopolitical issues should be as current as possible, and be relevant to the students themselves. If the environmental problems presented in class are especially topical, students may be able to draw connections to content and skills from other courses. Furthermore, it may be motivational for teachers to use inspiring role models (from the celebrated to the locally heroic) presented through a historical focus in videos and texts, or as guest speakers. This

curricular shift should be accompanied by a pedagogical shift that focuses on student-centered discourse, in which students are encouraged to develop and reflect on their worldviews in order to consider environmental challenges through a lens of environmental justice. Such instructional strategies rely on inquiry-based practices, as students would be encouraged to ask questions and explore phenomena with a teacher acting as facilitator of learning.

Followed by whole-class and small group discussions, assessments should be authentic, and can include written and artistic assignments to leverage student expression. It is worth noting that, as suggested by the students, surveys and interviews themselves could serve as assessments of and for learning, rather than traditional quizzes and tests that encourage the pursuit of numerical grades, rather than personal growth and civic engagement.

Changes in pedagogy that lead to improved learning experience for high school environmental science students will have to align with changes in the Next Generation Science Standards. Because Schweingruber, Keller, and Quinn (2012) did not include applicable aspects of the social sciences in the framework for the NGSS, the present findings are worth considering when the standards are revised in order to fill the gap the sociopolitical approach. Environmental science education should rely on socioscientific issues, especially if they lead students to consider sociopolitical action that advocates environmental justice.

A sociopolitical approach will address all three dimensions of the NGSS. It will augment the purpose of science and engineering practices. In addition, the Crosscutting Cutting Concepts are improved by enhancing the interrelationships among not only

scientific disciplines, but also other social domains such as morals, ethics, and politics. Finally, and most specifically, a sociopolitical approach can lead to changes in disciplinary core ideas in Earth and Space Science and Engineering, Technology, and Applications of Science. The present study joins the current wave of research that politicizes science education itself to influence changes in the NGSS in an effort to more justly fulfill the promise of science for all students.

A Look Ahead/Conclusion

This chapter described the key quantitative and qualitative findings for this study, followed by the integration of data collection and analysis to propose recommendations for improving the learning experiences of high school environmental science students. The dissertation continues with chapters five and six, which are manuscripts to be submitted to peer reviewed journals for publication. The implications of the findings are explored. The article prepared for chapter five and submitted to the *Journal of Research in Science Teaching* focuses on the potential for a sociopolitical approach (i.e. environmental justice) to motivate high school environmental science students. The manuscript prepared for chapter six and submitted to *The Science Teacher* focuses on the using the experience of being a practitioner-researcher to improve science teaching practice. The findings were presented at the winter conference of the Alliance for New Jersey Environmental Education.

Chapter 5

"There is freedom in doing science": Exploring the Potential to Motivate High School Environmental Science Students through the Lens of Environmental Justice

Abstract

The adoption of the NGSS heralds America's commitment to STEM education. However, recommendations on how to motivate students who have been disengaged with science rarely include suggestions for other dimensions of scientific practice, such as civic engagement. In this mixed methods, design-based study, we explored the potential for socioscientific issues framed by environmental to motivate high school environmental science students. The embedded design began and ended with a survey of student dispositions, and included interviews of particular students in an effort to capture views of general and personal dispositions. We found that students have an abstract notion of the environment that requires innovative approaches to teaching environmental science, and that students may view scientists as essential change agents in the face of environmental challenges. In addition, we found that a socioscientific approach framed by environmental justice empowers and motivates students and that a STEM approach alone is insufficient to motivate high school students. We make recommendations for transforming environmental science instruction through changes in lesson design and the NGSS.

Keywords: Environmental justice, environmental science, socioscientific issues, student motivation

As science teachers across the nation began to implement the Next Generation Science Standards (NGSS), they were challenged with changing their curricula and

pedagogy to meet new expectations, such as the emphasis on science and engineering practices to reflect a shift toward STEM education. Uniting science, technology, engineering, and math into a cohesive curriculum that promotes real-world applications, STEM education is meant to provide an avenue to STEM-based college majors and careers. Therefore, at the high school level, teachers of traditional sciences (biology, physical science, chemistry, and environmental science) are expected to implement lessons that encourage students to pursue careers in fields ranging from computer science to engineering. While the National Research Council (NRC) (2015) offered a conciliatory recommendation against replacing all curricular materials at once, Zeidler (2014) described this transition as "a bandwagon that has moved at nearly light speed" (p. 11). Others worry about what pedagogical practices science teachers may lose as STEM education colonizes their classrooms with the intention of bolstering the workforce and national security (Achieve, Inc., 2012; Rodriquez, 2015).

To counter the hegemonic effects of the STEM college and career pipeline, Zeidler (2014) proposed the use of socioscientific issues, which are topics that "require students to engage in dialogue, discussion, and debate" (Zeidler & Nichols, 2009, p. 49). With moral and ethical implications, such issues are also controversial and open-ended (Sadler, Chambers, & Zeidler, 2004). Reconceptualizing science education through this pedagogy is progressive, and even transformative, due to the complex knowledge and skills developed in such learning activities. However, unmotivated students could be better served by a sociopolitical approach that focuses on social justice, advocacy, and engaging students as active participants in their communities (Hodson 2003; Rodriguez; 2015; Zeidler, 2014). The purpose of this study was to explore the potential to motivate

high school environmental science students through a socioscientific approach framed by environmental justice. In an effort to track changes in student dispositions, this mixed methods study began with an initial quantitative phase through the administration of a survey administered to gauge overall dispositions among the students, highlight potentially unique participants for the qualitative phase of the study, and inform lesson design. Semi-structured interviews, influenced by narrative inquiry, comprised the qualitative phase and provided insight into students' experiences in an environmental science class. A design-based research methodology undergirded the study, as lesson design represented an intervention to be developed, implemented, and evaluated during practice (Anderson & Shattuck, 2012). The findings indicate that a socioscientific approach to environmental science may motivate students, especially when environmental justice frames course content.

Literature Review

This review explores the nature of scientific literacy to understand the purpose of science education. In addition, we examine the potential to situate student motivation in light of inquiry-based practices. Finally, we reflect on the trajectory of a politicized pedagogy that uses sociopolitical issues framed by environmental justice.

Contesting Neoliberal Science Education

According to NGSS Lead States (2013), the purpose for learning science is to prepare students to be "informed citizens in a democracy and knowledgeable consumers," as a K-12 science education will prepare them for college and science-related careers to bolster a competitive nation and lead the global economy. However, Schindel Dimick (2015) and Carter (2016) criticized these goals as neoliberal for placing the burden of

environmental stewardship on corporations and individuals as consumers and producers of natural resources. Thus, the responsibility is thrust on private citizens to solve problems through technological and engineering solutions, rather than through public civic participation. Schindel Dimick (2015) sided with scholars such as Chawla and Cushing (2007), Jensen and Schnack (2006), and Schusler, Krasny, Peters, and Decker (2009), who foresee environmental education geared toward the development of "students' civic capacities and dispositions to engage as participatory citizens in relation to environmental issues and concerns" (Schindel Dimick, 2015, p. 3). The unilateral STEM-based view precludes the development of a truly well-rounded citizen, and becomes especially problematic when we look at environmental literacy as a specialized scientific literacy.

In the 21st century, environmental literacy emerged as a component of scientific literacy, which initially concerned science content that students should learn to apply scientific knowledge and thinking to everyday life (DeBoer, 2000). With such limited vision, a perspective creates inequity in the face of the ongoing democratic motto *Science For All* when scientific literacy goals do little more than promote appreciation of its beauty (DeBoer, 2000). Uniting an understanding of ecology, a commitment to problem solving, and cultural sensitivity, Hollweg, Taylor, Bybee, Marcinkowski, McBeth, and Zoido (2011) defined environmental literacy by integrating knowledge with feelings, priorities, motivations, skills, and actions:

> An environmentally literate person is someone who, both individually and together with others, makes informed decisions concerning the environment; is

willing to act on these decisions to improve the well-being of other individuals, societies, and the global environment; and participates in civic life. (p.1)

Most relevant to this study is their list of dispositions that contribute to environmental literacy: "sensitivity; attitudes, concern, and worldview; personal responsibility; self/efficacy/locus of control; and motivation and intentions" (Hollweg, et al., 2011, p. 4). Therefore, environmental literacy is a comprehensive and holistic approach to understanding the natural world and our connection to it, rather than a toolbox of knowledge or skills.

Environmental literacy includes domains such as climate literacy and energy literacy, which focus on sustainability (U.S. Global Change Research Program, 2009). The United Nations Decade of Education for Sustainable Development (2005-2014) program sought to mobilize educational resources of the world through the following issues: Biodiversity, Climate Change Education, Disaster Risk Reduction, Cultural Diversity, Poverty Reduction, Gender Equality, Health Promotion, Sustainable Lifestyles, Peace and Human Security, Water, and Sustainable Urbanization. However, Feinstein and Kirchgasler's (2015) analysis of the NGSS reveals a narrow approach to these issues, and judged the NGSS insufficient in preparing students to address sustainability. Due to the standards' technocentric approach, they deemed the NGSS insufficient to prepare students for the ethical or political challenges they would face in an environmental science course. In their framework for the NGSS, Schweingruber, Keller, and Quinn (2012) omitted certain disciplines, claiming that it was not their original purpose to include fields such as social sciences, economics, or political science in K-12 science curriculum. Feinstein and Kirchgasler (2015) called on science teachers and social studies

teachers to collaborate to provide realistic, interdisciplinary lessons that prepare students to tackle the challenges of sustainability in particular. Kaya and Ebenezer (2007) found that students developed more positive attitudes toward science itself, as well as more self-confidence, through authentic research projects. With a limited purpose of environmental science (besides the goals of STEM), the potential to motivate students may also be limited (Pintrich, 2003).

Motivating Science Learning

Mastery-based goals, such as earning good grades or earning acceptance into college, do little to motivate students who are not intrinsically motivated by learning (Pintrich, 2003). Therefore, Pintrich (2003) offered additional sources of intrinsic motivation: adaptive self-efficacy and perceptions of competence, personal interest, and values linked to personal identity. If affective constructs lead students to strive for mastery, or at least the avoidance of failure, then purpose can serve as motivation, which varies among students, and across time (Pintrich, 2003; Seifert, 2004). Seifert (2004) proposed a productive learning environment based on emotions and beliefs in addition to social and cognitive motivators.

Interest is a key intrinsic motivator that develops through four phases that include both cognitive and affective aspects (Jarvela & Renninger, as cited in Sawyer, 2014). Once triggered, interest may develop into a deeper individual interest. Discrepant events may spark interest by catching students off-guard and inviting inquiry (Llewellyn, 2005). This research seeks to capitalize on the development of interest in environmental science, by fostering the maintenance, emergence, and sustenance of individual interest, cultivated by each learner's curiosity and concern (Hidi & Renninger, 2006). Interest is fluid and

malleable based on peer interactions, learning tasks, and learner support (Jarvela and Renninger, as cited in Sawyer, 2014). Pickens and Eick (2009) found that hands-on learning activities that facilitated dialogue and confidence-building intrinisically motivated lower-track students.

The identity-based motivation model presents motivation as a socially dynamic construct concerned with identity in learning experiences, such that students need to feel they can picture themselves being successful in what they are learning, and that those activities are for "people like them" (Oyserman & Destin, 2010, p. 1018). When Lin-Siegler, Ahn, Chen, Fang, & Luna-Lucero (2016) attempted to motivate students with role models, positive effects of identifying with struggling scientists were pronounced among underperforming students. Less successful and under-represented students relegated to lower tracks are further marginalized when they convince themselves that they cannot be successful, and enter into a subculture that identifies with deliberate failure (Yerrick, 2000). Perceptions of self-efficacy interdepends on interest and identify, which forms the foundation of student motivation (Seifert, 2014).

Inquiry-Based Practices

Inquiry has its roots in the work of John Dewey (1910), who stressed active learning and interactions with the natural world (Nathan & Sawyer, as cited in Sawyer, 2014). The National Science Teachers Association embraced inquiry as an instructional strategy through the definition provided by the NRC (1996): Scientific inquiry represents "the diverse ways in which scientists study the natural world and propose explanations based on the evidence derived from their work" (p. 23). Inquiry reflects both how scientists traditionally conduct research, and how science teachers can facilitate learning

centering on students' questions. While the framework for the NGSS does not offer as clear a definition, it builds on these same philosophical underpinnings (Schweingruber, Keller, & Quinn, 2012).

While inquiry may reflect authentic scientific practices that can engage all students, current research reflects a bias in student learning that implicates the nuanced learning environment that Seifert (2004) suggested needs to be adaptive and constructivist (Brickman, Gormally, Armstrong, & Hallar, 2009; Shaw & Nagashima, 2009; Zohar & Krasinski, 2005). Dalton, Morocco, Tivnan, and Mead (1997) found that both general education and learning disabled children had greater success learning scientific concepts through supported, constructivist inquiry than through hand-on activities, although Shaw and Nagashima (2009) uncovered underperformance in inquiry-based instruction by the following student sub-groups compared to their counterparts: Blacks, Hispanics, low socioeconomic status students, males, non-gifted, and special education students (Shaw & Nagashima, 2009). Thus, scientific inquiry itself may not motivate struggling students.

Focusing on the socially interactive nature of inquiry, Whitworth, Maeng, and Bell (2013) differentiated inquiry-based instruction by applying six tenets described by Tomlinson and Imbeau (2010) as best practices to align with different learning levels based on teachers' ability to modify or tier activities. These tenets, which stress respect for students, diversity, reflection of our society, equity, and capacity building of learners, reflect morally transformative education (Boyd, 2009). Furthermore, Patrick and Yoon (2004) found that student motivations changed with changes in their understandings. Therefore, differentiation of motivation is as essential as differentiation of instruction

itself, for both strategies require close attention and flexibility on the part of the teacher to engage students (Patrick & Yoon, 2004).

Implicating social constructivism, motivation depends on more than pedagogy itself. Affective interactions between students and teachers, as well as among students, cultivate motivation (Varelas, Becker, Luster, and Wenzel (2002). While inquiry may be effective for academic achievement, attention to motivation to learn may have multiplicative effects through a complex interplay of variables. Interest may develop from a neutral starting point and lie on a spectrum of engagement ranging from commitment to alienation, when examined in light of conduct and on-task behavior (Fredricks, Blumenfield, & Paris, 2004). Again, motivation includes emotional and behavior outcomes, not just cognitive ones.

An inquiry-based, sociopolitical nature of environmental education would require multifaceted attention to motivation. As a transformative component of science education, environmental justice adds an element of socio-political action to environmental literacy, and to the learning experience itself. This premise requires an examination of not only what is taught in science classes, but also *how* science is taught. Butler (2009) explored three main approaches to motivation (realness, rigor, and relevance), which reflected the precepts of culturally relevant teaching: critique, competence, and relevance (Ladson-Billings, 1995). In turn, learning culminates in critical consciousness in active citizenry through cultural competence, which can be leveraged for not only student achievement but also for empowerment Dimick (2012).

Benzce and Carter (2011) built on Hodson's (2003) call for politicization of the curriculum, and reframed student empowerment as a form of social justice. Their highly

critical work stressed the link between a hyper-economized society, environmental degradation, and oppression. In their view, STEM-based science education has become a means to plug students into a globalized society obsessed with capitalism. However, their call for teaching activism in science class to question the status quo was limited to providing theoretical frameworks. Bazzul (2013) applies Ranciere's (2011) notion of radical equality to connect pedagogy with politics in science education by introducing value-laden discourses in which the situated voices of the learners come forth (p. 250). However, before science education jumps the track for a new set of rails, Rudolph and Horibe (2016) suggest that we harmonize the goals of science education to integrate technical training, as advanced by STEM, and civic engagement, as promoted by advocates of sociopolitical action.

A Sociopolitical Approach to Science Education

Hence, a sociopolitical approach to science education evolved in light of global issues such as climate change. Schneider, Krajcik, Marx, and Soloway (2002) cited motivation towards action and the accumulation of sufficient knowledge as assumptions for student empowerment. Therefore, science education could become a means of empowering citizens, enabling them to make personal decisions on matters such as climate change, as well as act as participants in social change regarding such global issues. The development of critical thinking, not just literacy, is essential for students to be able to understand the social issues we face, and the ability to make intelligent decisions about them (Abrami, Bernard, Borokhovski, Waddington, Wade & Person, 2014). Schindel Dimick (2012) applied McQuillan's (2005) framework for student empowerment, to outline social justice science education, which empowers students

academically, socially, and politically. Transitioning to a local context, Tolbert, Snook, Knox, and Udoinwang (2016) successfully implemented this pedagogy at a public charter school.

With increasing complexity, scholars recognized the environment itself as a social construct that initially comprises our habitat, which depends on the sociocultural framework in which we develop our societies (Hodson, 2011; Pedretti & Hodson, 1995). Science can be viewed as patently value-laden especially when we consider moral obligations to address sustainability (Dimick, 2012). Thus, a critical pedagogy questions the status quo of both environmentalism and environmental education, and challenges the anthropocentric worldview that places humans above all other organisms and supports our right to modify environments and exploit natural resources (Schindel Dimick, 2015). Environmental education that rebuts neoliberalism fosters the development of environmentally conscious citizens who confront multiple discourses (Schindel Dimick, 2015). Thus, both the environment and environmental science are socially situated. Therefore, science education can be viewed as a realm of empowerment in addition to employment, although science education starts with the expectation that all citizens develop the literacy needed to critically consume scientific information, regardless of the application (Schweingruber, Keller, & Quinn, 2012).

Methods

This purpose of this study was to explore the potential to motivate high school environmental science students through a socioscientific approach framed by environmental justice. To track changes in student dispositions, this mixed-method study began with an initial quantitative phase through the administration of a survey modified

from the Relevance of Science Education project (Jenkins & Pell, 2006). The survey was administered to establish a baseline of overall dispositions among the students, to highlight potentially unique participants for the qualitative arm of the study, and to inform lesson design. Semi-structured interviews, which were influenced by narrative inquiry (Clandinin & Connelly, 2000), comprised the qualitative phase and provided insight into students' experiences in the environmental science class under investigation. Through a design-based research methodology, our curricular unit represented the intervention to be developed, implemented, and evaluated during practice (Anderson & Shattuck, 2012). Pursuant to an embedded mixed methods design, the survey was re-administered at the end of the introductory curricular unit with time for interview participants to address their pre- and post-survey responses in interviews, enabling the mixing of data from the two strands (Creswell & Plano Clark, 2010).

This study was structured to answer the following research questions:

1. How do student dispositions towards science in society change as a result of studying environmental science?
2. How do student dispositions towards environmental justice change as a result of studying environmental science?
3. What insights emerge from the stories told by high school students about their experiences in Environmental Science when taught through the lens of environmental justice?
4. How can these findings be used to improve the overall learning experiences of high school environmental science students in an era of the Next Generation Science Standards?

Pre-Study

The opportunity to rejuvenate an Earth Science course gave rise to Environmental Science, which remained the third in a lower-track sequence of lab-based sciences required for graduation. The curriculum has been revised annually with student motivation in mind. The curriculum has become more heavily influenced by educational initiatives that advance STEM college majors and careers. However, few of the students who take the course have ever expressed interest in pursuing such fields. The reliance on experiential learning through inquiry-based activities has led to more hands-on lessons than minds-on explorations. The construction of a rain garden with outdoor furniture has done little to motivate student interest in the outdoors; that many students decline the opportunity to spend class outside signals a lack of environmental interaction, and perhaps environmental literacy. With an increasing number of students hailing from urban settings, and more students failing the course each year, the stage was set for a new approach that focused on relevant and authentic learning experiences.

Context

The research was conducted at a high school in the NJ suburbs of Philadelphia. Among the 1450 students, the majority (55.6%) are White, 33.7% of the students are Black, 5% are Hispanic, 4.6% are Asian, 0.7% are American Indian. Thirty-one percent of the students are enrolled in the free and reduced lunch program and 12.6% of the students are enrolled in special education services (NJ DOE, 2015). It is culturally and socioeconomically diverse. The science learning environment consists of 15 lab desks meant for pairs of students, but accommodating of groups of four students. It includes a

Wi-Fi-enabled laptop cart and a rain garden furnished with chairs hand-made from upcycled wood pallets that serves as an outdoor classroom.

Participants

Seventy students in four sections, including the inclusion section, took the initial survey. However, only thirty took the follow-up survey, despite numerous opportunities for students to take the survey during lessons, such as when assignments were completed ahead of time or when computers were available during collaborative lessons. While 24 students expressed interest in participating in the qualitative research, only six students committed to interviews. They represented all four sections of the course and are described in more detail in Table 1.

Survey Phase

At the beginning of the school year, students were asked to complete a survey adapted from the ROSE project (Jenkins and Pell, 2006). Administered through Google Forms, the survey consisted of 15 items that explored dispositions on science in society and environmental justice, on a Likert scale of 10. As the unit concluded, the students were asked to take the survey again. Students who committed to interviews took the survey ahead of their scheduled interviews to have the opportunity to explain the changes in their dispositions.

The findings of the initial survey gauged overall changes in dispositions, helped us identify potential interviewees, and informed the intervention. We calculated Z-scores following calculations of means, to identify students based on their average responses' distance from the mean. We approached students with the highest Z-scores, especially if they identified as willing to participate in further research. Following data analysis, we

concluded that the students would benefit from a socioscientific approach featuring lessons based in environmental justice.

The third goal of the quantitative phase was to track changes in student dispositions as a result of studying environmental science. The data were further analyzed through the calculation of variance, a correlation analysis, and a two-tailed t-test.

Qualitative Phase

We conducted semi-structured interviews after school that lasted approximately one hour each. The eight questions included prompts about changes in students' environmental ethics, their opinions on specific environmental problems, and their perspectives on ways to address environmental problems in light of their perceptions of society. Influenced by narrative inquiry, we wrote analytical memos containing a brief biography of each student as they experienced our environmental science class. Coding allowed for sense making; qualitative analysis began with a cycle of in vivo coding, which prioritizes and honors participant's voices by assigning codes taken directly from the transcripts. This method is appropriate for explorations involving marginalized youth because "coding with their actual words enhances and deepens an adult's understanding of their...worldviews" (Saldaña, 2013, p. 91). Analysis continued with values coding, an affective method that reflects participants' values, attitudes, and beliefs (Saldaña, 2013). These concepts align with dispositions, which are a focus of the research questions (Saldaña, 2013). We based a final coding cycle on Labov and Waletzyky's (1967) structural model, to prompt a biographical story of each interviewee's stories, representing the transition of field texts to research texts, using the students' voices (Clandinin & Connelly, 2000).

Findings

Quantitative and Curriculum Development Phase

Pre-test survey results. The findings of the initial survey informed the intervention, helped us identify potential participants for the qualitative strand of the study, and gauged overall changes in dispositions. After calculating the means and medians of the initial survey, we determined that the students would benefit from a socioscientific approach featuring lessons based in environmental justice. Student responses were skewed in agreement with most survey items. Most notably, students generally agreed that environmental problems would affect them ($\bar{x}$ = 7.2, SD = 2.7). However, they expressed ambivalence regarding the role of experts in environmental decision-making ($\bar{x}$ = 5.0, SD = 3.1) despite valuing morals in the same process ($\bar{x}$ = 7.5, SD = 2.6). Helping students see themselves as change agents became a teaching objective.

Curricular design. We decided that motivating students through sociopolitical action was an appropriate target for lesson design. Overall, students were ambivalent in their perception of the role of science in society, and in matters of environmental justice. We developed lessons in which they explored their morals in light of their dispositions about the role of science in society. By reflecting on their worldviews, students were encouraged to develop the attitudes that predispose them to environmental literacy. These lessons were implemented through small-group and whole-group discussions, collaborative concept mapping, expository writing assignments, and a summative assessment in the form of a case study on food deserts. Current news articles and videos were selected to prompt the development of scientific understanding that students could

consider in light of their those dispositions. Students were regularly asked to verbalize or write about their environmental ethics, spanning anthropocentrism, biocentrism, and ecocentrism.

Post-test survey results. There were no statistically significant changes in students' dispositions towards science in society. On the other hand, there were several statistically significant changes in students' dispositions towards environmental justice. There was a significant increase in students' recognition of the potential for environmental threats to affect them (pre $\bar{x}$ = 7.2, post $\bar{x}$ = 8.6, p = 0.01). In addition, they recognized a greater connection between environmental problems and social problems (pre $\bar{x}$ = 6.1, post $\bar{x}$ = 7.8, p = 0.00), which reflected the instructional focus on inequity in communities, especially urban areas. As a whole, students agreed more strongly with the need to consider morals in environmental decision-making (pre $\bar{x}$ = 6.6, post $\bar{x}$ = 7.8, p = 0.025).

Qualitative Findings

Four key insights emerged from the stories told by high school students about their experiences in environmental science when taught through the lens of environmental justice. Students' perceptions of the environment diverged from a traditional nature-based perspective, to a human-centered view that the environment connects to society. Secondly, students came to see scientists as essential change agents, not just explorers and inventors. Also, students demonstrated empowerment through this approach. They attribute motivation to this pedagogy, rather than a STEM focus alone.

Student perceptions of the "environment." The students equated the environment with being outside, especially if they were away from urban environments.

Despite minimal contact with nature, they were confident in defining the environment, and expressing appreciation for it. With little overall connection to natural environments, they cited parks and gardens as peaceful places in which they could relax or play. Andrew described his experience with natural settings:

> I used to take a lot of walks in my woods that are around my house with some people, but yeah, I appreciate it. I enjoy it to an extent, like we have a garden in my house, you know, I go out there and look at it and I water plants for my mom. Beautiful things like birds chirping; it's just things like that.

Hugo justified this disconnect: "Most people that live somewhere where there is more nature than others would be more focused on nature because that affects them more directly." In their eyes, the environment is comprised of commodities such as water, air, and lumber that provide them the stuff we need to sustain society, without reasoning about direct impact. Hugo expressed concern over his "local water supply." On the other hand, Katrina extrapolated her definition of the environment to "reefs and the ocean and stuff." Essentially, they reflected a consumerist approach to the environment, in that their descriptions focus more on goods and services that the environment provides.

Their distanced perspective led to an abstracted notion of environmental problems and remedies. They illustrated the environment in terms of its overall declining condition. Dayle described the environment as "getting too hot. We have less rain and the time we do get rain, it comes down in one giant downpour and then after that we can go months at a time without any water falling." Hugo observed, "Our environment is constantly evolving because of the humans' impact on the world." In agreement with Hugo, Matthew optimistically opined, "We know the environment is in bad shape, not the worst

shape as it was once, but it's in a bad shape." Andrew worried about "driving an animal to extinction; it could obviously cripple the whole food chain or something like that, and that could affect not just us, but everything." Their recognition of environmental damage supports their concern for it, rather than the direct harm that befalls them. While slightly exaggerated, their worry suggests ecocentrism, in that they are concerned not just with living things, but also the abiotic factors and ecological interactions that sustain natural systems as a whole. Regardless of its source, such an ethic is worth cultivating to motivate students to engage in science.

The students focused on the environment's need for repair. Hugo elaborated on an environmentalist point of view:

> Climate change, for example, was controllable but now it's something that just has to repair itself and we have to aid it in that, but we cannot completely control it. We can drive cars that don't have emissions, we could stop burning things, we cut down on anything that harms the environment, but it's up to the environment. We can aid it completely, but like I said the environment it has to fix itself. Aiding it is just a major part but in order for it to completely heal and prosper again, which I wouldn't say that it's not prospering well, it's damaged, but it's still alive.

They generalized the impact of environmental damage by vilifying human activities such as fossil fuel combustion and deforestation. Students were motivated by appeals to their sense of right and wrong; an affective approach fostered interest in environmentalism.

Following this unit, the students expressed concerns about environmental issues that double as societal issues. Problems such as food deserts implicated poverty and

discrimination. “Only the poor people live in a food desert you know,” Katrina declared. Matthew expanded on this situation:

> Food deserts, for example, like there’s a problem with that, they start to realize that. How can they fix it? They're going to use environmental things like growing gardens and community gardens to fix that. Eventually, they’ll realize, “We can do this, now how can we, like, eventually kind of fix the whole environment?”

Thus, framing environmental problems as social problems increased students’ sense of agency. While students sympathized with environmental problems for the environment’s sake, they also worried about social ills such as poverty and hunger. Recognizing the connection between the environment and society led to a sense of environmental justice that appealed to their sense of right and wrong. Students cited limited access to resources and suffering from pollution as environmental injustice. Thus, they considered sociopolitical actions such as petitions and protests among the solutions to environmental problems. In conclusion, despite little personal connection to natural environments, students who participated in the interviews appreciated the interconnectedness and interrelatedness of the environment and society, through problems that overlap the two domains.

The role of scientists in society. Scientists, once seen as people who explore and discover natural phenomena, were seen by students as people who confront problems in the so-called environment. As Matthew said, “I think that now, science needs to evolve into the idea that they need to do something, and they can do it.” Hugo concurred: “There should be scientists that are trying to figure out ways that will better the environment. Then it will just better the environment in other ways.” Environmentalists connect

science and action, as students learned about grassroots activists such as Ron Finley, who establishes community gardens in his South Los Angeles community. Because students considered gardens to be an "environment," they exemplify both scientific experimentation and environmental advocacy.

In the students' eyes, the practice of scientific research continues with developing and proposing solutions. Andrew proposed that scientists participate in policy-making:

> If they have extensive knowledge of what's going on, they can definitely help. Maybe they shouldn't directly write the statements maybe, but they can definitely put their inputs into them. They can tell them how they feel and they can improve what's going on.

It is interesting to note Andrew's consideration of scientists' feelings, for students experienced the development and expression of opinions with emotion, in addition to argumentation. Thus, expression of emotion is an emergent trait of scientists in this field. Ivan expressed a synergy in society that reflects the impact of a socioscientific approach: "If other people are all agreeing to the scientist and the policy at the same time, I feel like it will be a better connection to each other that would make things easier." Collaboration between scientists and policy-makers echoes the integration of environmental problems and social problems. Focusing on individuals' roles in both science and decision-making clarifies the meaningful involvement espoused by environmental justice. Writing environmental policies provided students an authentic opportunity to enact the role of an environmentalist, by applying both scientific knowledge and political skills, by capitalizing on the congruence between sentiments and the potential to act on them.

Classroom attention to the pipeline protests in North Dakota highlighted this notion of the contemporary role of scientists. In September of 2016, protests led by Sioux tribes against the construction of the Dakota Access Pipeline drew national attention. As the Sacred Stone Camp of activists grew in size and tension throughout the fall, the controversy surrounded the pipeline's construction illuminated the intersection between environmental protection and indigenous rights. Hugo illustrated the importance of scientists in environmental decision-making:

> Scientists belong in every aspect, really, because with the pipeline near the Sioux, if there were scientists and people that care about the environment involved in this, the pipeline probably wouldn't be built. There wouldn't be fighting for it. There wouldn't be people being arrested. There wouldn't be people that are struggling to fight this.

To the students, scientists were respected, and necessary, fixtures in society. Students recast scientists as change agents who are civically engaged to advocate for communities, especially marginalized or impoverished communities. Envisioning environmental scientists as activists, the students created protests signs that displayed evidence to support their opposition of pipelines. This authentic assessment of their learning presented them an opportunity to practice science for sociopolitical action. By Tweeting pictures of their signs and posting them on the school walls, they were proud to make their voices heard.

According to students, scientists should be empowered with resources and through civic engagement to ensure a safe environment for all citizens, who in turn should support scientific activities. Dayle said:

> When it comes down to the scientists, the actual people who are trying to figure out a solution and tell the politicians who just ignore them, where is the voice of the people?

Such expressions demonstrate the potential for scientific practices to support democratic activities. By displaying their protest signs, students were not just mirroring the actions of activists. Through freedom of expression, students realized their potential to work in the service of their communities, as activists or scientists, or both.

Empowerment through a sociopolitical approach. A sociopolitical approach to learning environmental science empowered students per Dimick's (2012) framework for social justice science education, comprised of three dimensions: academic, social, and political. First, students were empowered academically by learning about complex environmental problems. The realism and relevance of socioscientific issues impressed Hugo:

> We learned about what's happening in the world, of what the pipelines are capable of doing, and when we collaborated we found out a lot of things, like the pipelines and how they can have a negative effect on nature...You're not just teaching us the world of science, you are also teaching that other people matter.

The complex issues required higher-level thinking. Dayle observed:

> It makes us actually start thinking. It makes us start thinking and it makes us process things faster. It makes us conclude our opinions from the other opinions of other people, and then think of more and more opinions and solutions.

Relevant lessons cultivated ongoing curiosity. Katrina explained, "I am going to still keep everything in mind because you know, things are constantly changing and as long as I

keep myself updated and informed of certain stuff I know I am going to...pursue it continuously." By studying the interconnectedness through collaboration, students became invested in learning, and impressed with the depth of their own learning, thereby creating in a positive feedback loop.

Thus, the students' motivation reflected social empowerment, which created a contagious effect in the classroom. An advocate of whole-class discussions, Andrew proposed, "If we have more people working on it, more people just simply contributing their thoughts and their views, we can get further with it." Hugo described the energy that empowered students exude:

> I could be talking about the subject and it does get a little heated but there are some students in my class that constantly have opinions and they are very interesting and I never looked at it in some way but this is definitely the way I feel like environmental science should be taught.

The students valued collaboration and unity in addressing their community's needs, as promoted in the classroom. They espoused the need for science students to learn social skills that support sociopolitical activism. Thus, their social empowerment intersected with political empowerment.

Ultimately, their political empowerment reflected their civic engagement. The students strived for participation not only in class, but also in society. They worried about inequity and injustice, especially among marginalized and underserved people depending on race, sexual identity, indigenousness, and socioeconomic status. Students, such as Ivan, saw themselves as concerned scientists:

> I definitely went home and filled my glass with water and looked in it there, and was like, "Is there lead in there?" That's kind of what I did…Just because there is lead somewhere else in the water doesn't mean that that can't get to where we're at. It's definitely is going to be a problem. So I have to worry about somebody else's water. Then I'm going to start thinking there is lead in my water. I don't want lead in my water so I'm going to be scared and nervous to test it, so I'm probably not going to want to test it. I think I will, just for the sake of other people...if they don't want lead in their water...I don't want to have that problem so I definitely would test the water just to make sure that it's safe, not just per se. If I'm going to water my plants with the same water, I think that lead in that water will affect me too.

Ivan's concern about water pollution led to agency. He realized his ability to monitor the environment on behalf of his community. Students' perceptions of scientists aligned the environment and society to their own responsibility for the sustenance of both.

Student participating in the interviews saw themselves joining or even coordinating protests, and signing or creating petitions to confront business practices or political agendas that ignore environmental protection. The three types of empowerment reinforced each other in a virtuous circle, fostering a democratic and participatory learning environment.

"There is freedom in doing science". While admitting that STEM is useful, students maintained that a sociopolitical approach is necessary to motivate students through an awareness of the problems their generation faces and a sense of purpose and

empowerment. Ivan suggested how a STEM program would be limiting to students in the future:

> If you can only teach about how it is being built, I don't think that would almost be really fair, because I feel like they should be able to know what's going on, how it's happening, like going on in their community. If something was being built in my community, say there was a new water tower being built two streets from my house, I would want to know...how it's being built and why.

Exploring the societal implications of solutions to environmental problems motivates students. Exemplifying math through graphs and arithmetic, students seemed unenthused by eliminating socially dynamic learning. While they saw value in integrating engineering and technology, they did not claim to be motivated by those disciplines, except for using social media as part of their learning experiences. Therefore, they contend that science education is incomplete through a STEM approach. Although they could justify it, they declared it insufficient to motivate themselves and their classmates.

The use of socioscientific issues offered the potential to develop holistic science lessons that encompass language arts and history, in addition to the complementary STEM fields. Andrew contrasted the stifling nature of STEM with the freedom of our approach:

> There is freedom in doing science...but is there freedom at the same time if you're not allowed to make the policies or do anything like that anymore, which I feel like is a big thing? Because making policies lets you put your opinion out there instead of just simply making a graph, collecting data.

The sociopolitical approach takes the STEM approach a step further in a way that students deem necessary. Katrina described the power of history to add a sense of perspective and relevance:

> If you incorporate history into science and you say like well, you know, in 19[hundred] or 18[hundred] you know, whatever had happened, and this was the cause, it be like, "Well, now we see it progressing back to what happened, what we can do to stop it." I feel like that would help, if you want to really incorporate everything.

A sociopolitical approach includes a pedagogical shift preferred by students. Beyond drawing conclusions, they could reflect on history to express themselves in a way that has more purpose, which motivated them. They connected the past to the present, in which they felt authentically involved.

Students in the qualitative phase favored science lessons devoted to socioscientific issues because, much like the aforementioned humanities, they allowed students to explore their values and viewpoints, express themselves, and communicate with each other. Andrew described Environmental Science as "the most outgoing and forward class I've had for science so far." He attributed the impact on the instructional approach: "The projects, we do things like that, but the talking is a huge part." Katrina elaborated: "This class is not just regular science and chemicals and stuff like that. It's everything. It's a lot. It incorporates not only science things. It incorporates your political standing with your personal values." Thus, Hugo realized how a cross-curricular approach could engage students:

> They [the courses] all connect in some way or another...They shouldn't be bounded by science or math...Science is a way to do something, or just a way to learn about something or it's just a default thing. Science can be anything from political, to social, to environmental, to biology, about the stars...It can make that the course or that whole field better and enhance it.

Ultimately, students compromised with a suggestion that the two approaches be incorporated in tandem. On one hand, STEM provides long-term practicality, but students found immediate purpose in a sociopolitical approach, which was seen as more personal and social. Especially impressed by the sense of fairness, equity, and inclusion that environmental justice promotes, the students were empowered by sociopolitical solutions because they can participate in those venues more readily.

Discussion

Our study contributes to research that seeks to improve education through direct participation of students. In the following section, we respond to our research questions to explore how student dispositions to science, society, and learning environmental science itself changed through the use of socioscientific issues. Both the quantitative and qualitative data support our pedagogy, which not only motivates, but also empowers, our students, leading to questions about the direction of science education in the era of the NGSS.

Student Dispositions

The first research question concerned changes in student dispositions towards science in society. Based on the quantitative findings, there were no statistically significant changes in students' dispositions towards science in society. The introductory

unit's focus on the sociopolitical facets of socioscientific issues may be responsible. The only true inquiry was a hands-on simulation about the Tragedy of the Commons using goldfish crackers. Rather than focus on large-scale fisheries management, we tailored the activity to focus on personal decision-making. Like Madosky (as cited in Byrne, 2016), we found that such decision-making is less the result of scientific knowledge than conscious choice. The use of socioscientific issues should be balanced pedagogically, as the relevance of such issues can be engaging both cognitively and affectively (Alsop & Watts, 2009).

The second research question concerned changes in student dispositions towards environmental justice. Statistically significant changes in students' dispositions reflect an espousal of environmental justice. Students' increased recognition of the potential harm posed by environmental problems such as water pollution and climate change, and the connection between those problems and societal problems reflected the instructional focus on inequity in communities, especially urban areas. As a whole, the students agreed considered morals important in environmental decision-making, likely owing to writing assignments on their environmental ethics, once identified. Informally, they espoused more biocentrism and ecocentrism than anthropocentrism, almost unanimously taking a stance against actions that risked environmental damage, such as pipelines and waste management facilities. Learning activities that support a sense of agency for enacting student views can sustain interest in science, especially if science can be shown to improve their lives (Basu & Calabrese Barton, 2007). The quantitative data supported the development and implementation of lessons reflecting a sociopolitical approach,

grounded in environmental justice. Students who participated in interviews were able to elaborate on their responses to these survey items.

Environmental Justice in the Classroom

The third research question sought insights about student's learning experiences. Four major findings emerged. The students described the environment in an abstracted way that focused their attention on natural resources, rather than nature itself. Optimistically, they viewed scientists as essential change agents in society. Furthermore, students were empowered academically, socially, and politically by socioscientific lessons taught through the lens of environmental justice (Dimick, 2012). With a heavy focus on the social and sociopolitical side of environmental issues, students preferred this approach to a STEM approach promoted by the NGSS.

Our pedagogy reflects transformational teaching theory (Boyd, 2009), which applies emotional intelligence and transformational leadership to instructional practice (Boyd, 2009). This theory supports effective pedagogy while fostering leadership via Bass' (1990) principles of transformational leadership: idealized influence, inspirational motivation, intellectual stimulation, and individual consideration. This theory supports the teacher as an environmentalist, scientist, and instructor by integrating teacher commitment to teaching environmental science through "green pedagogy" (Jorgenson, 2012; Sosu, McWilliam, & Gray (2008). Our facilitation of learning reflects motivation through instrinsic factors such as adaptive self-efficacy, perceptions of confidence, and personal interest (Pintrich, 2003). Through this approach, we leveraged affective variables (such as concern and care for the environment and others peoples), in addition to cognitive ones, en route to inspiring interest that cultivated empowerment.

Improving Learning Experiences

The final research question sought to apply the findings to improve learning experiences for high school environmental science students, through the mixing of quantitative and qualitative data. Data transformation and parallel integration provided a means to mix the data (Creswell & Plano Clark, 2010). Reflecting on their survey results during their interviews, students clarified what they meant (or what they thought they meant) when they took the surveys, and summarized their current impressions. The change in confidence the students espoused reflected the lessons and classroom environment that developed through the new curricular approach, which not only motivated, but also empowered students.

The expressions of confidence support the motivation model of Oyserman and Destin (2010), in which students connect authentically to their learning experiences, and reflect the conclusions of Brickman, et al. (2009) who connected inquiry-based learning with self- confidence. Furthermore, the sense of agency articulated by the students reflects the work of Daniels and Arapostathis (2005), who showed the potential to break the cycle of student disengagement through empowerment. Inquiry, supported by the development of confidence, is embedded in Blanchet-Cohen's (2008) stepwise framework illustrating students' development into environmental activists: connectedness, engaging with the environment, questioning, belief in capacity, taking a stance, and strategic action. Socioscientific issues leveraged students' emotions to motivate them to learn science through the development and application of morals and ethics that questioned their impact on the environment, and their role in society.

Socioscientific issues provided a relevant and realistic approach to environmental education that the students identified as interdisciplinary and valuable. Infusing lessons with environmental justice provided a lens of legitimate and meaningful involvement in their learning that students could immediately extend beyond the classroom. Students valued the communication skills practiced during lessons based on socioscientific issues They considered the authentic assessments that followed lessons in which they applied scientific content and skills to current events to be fair alternatives to traditional quizzes and tests.

Implications

Learning experiences for high school environmental students may be enhanced by a focus on socioscientific issues. Relevant and current course content, based on the DAPL protests and food deserts in local towns, was motivating in addition to empowering, through hands-on activities. When science teachers develop lessons around sociopolitical issues that are current and relevant to the students' experiences, students may draw connections to content and skills from other courses. Furthermore, role models (from the celebrated to the locally heroic) presented in videos and texts, or as guest speakers may also be inspirational, especially if their stories demonstrate struggles (Lin-Siegler, Ahn, Chen, Fang, & Luna-Lucero, 2016).

Students may be able to discover scientific concepts through the exploration of relevant issues (Zeidler, Applebaum, & Sadler, 2011). Inquiry-based practices may include student-centered discourse, in which students are encouraged to discuss their worldviews to consider environmental challenges through a lens of environmental justice in accordance with problem-based learning (Lu, Bridges, & Hmelo-Silver, as cited in

Sawyer, 2014). Followed by whole-class and small group discussions, assessments may be authentic, and could include written and artistic assignments to leverage student expression. It is worth noting that, as suggested by the students, surveys and interviews themselves may serve as assessments of and for learning, to measure personal growth and civic engagement, as opposed to the traditional reliance on quizzes and tests that encourage the pursuit of numerical grades. Authentic inquiry-based practices foster self-confidence in student abilities (Brickman, Gormally, Armstrong, & Hallar, 2009).

Changes in pedagogy that lead to improved learning experience for high school environmental science students must align with changes in the NGSS. Because Schweingruber, Keller, and Quinn (2012) did not include applicable aspects of the social sciences in the framework for the NGSS, the present findings are worth considering when the standards are revised in order to fill the gap the sociopolitical approach. Environmental science education may rely on socioscientific issues, especially if they lead students to consider sociopolitical action that advocates environmental justice while helping students accumulate sufficient knowledge to make decisions (Hodson, 2003; Schneider, Krajcik, Marx, & Soloway, 2002).

A sociopolitical approach addresses all three dimensions of the NGSS. It augments the purpose of science and engineering practices. In addition, the Crosscutting Cutting Concepts may be improved by enhancing the interrelationships among not only scientific disciplines, but also other social domains such as morals, ethics, and politics. Finally, and most specifically, a sociopolitical approach may lead to changes in disciplinary core ideas in Earth and Space Science and Engineering, Technology, and Applications of Science.

Conclusion

This research supports a shift in focus in environmental science education that motivates students through the fair treatment and meaningful involvement that the environmental justice movement espouses. Science education can remain inquiry based and STEM-oriented, but the use of socioscientific issues that motivate students and inspire sociopolitical action should be considered by environmental science teachers. An introductory unit based on environmental justice reflects a critical and interdisciplinary pedagogy may be transformative when learning depends on discourse that challenges core beliefs (Zeidler, Applebaum, & Sadler, 2011). Socioscientific topics engage students with ethical and political challenges not yet recognized by the NGSS, and encourage students to practice science in a democratic setting that empowers them for civic engagement and potentially motivates them for further involvement in science and society. The present study joins the current wave of research that politicizes science education to influence changes in the NGSS to more justly fulfill the promise of science for all students.

Chapter 6

Testing the Waters: Using Environmental Justice to Motivate Environmental Science Students

Abstract

The adoption of the NGSS heralds America's commitment to STEM education. However, recommendations on how to motivate students who have been disengaged with science rarely include suggestions for other dimensions of scientific practice, such as civic engagement or political participation. We explored the potential for socioscientific issues to motivate high school environmental science students. With those students, we administered surveys and conducted interviews, to develop lessons framed by environmental justice and gain insight into their motivation. We leveraged students' respect for morals in environmental decision making to foster change agency. Because students view scientists as essential change agents in the face of environmental challenges, we advocate for teachers to use socioscientific issues to advance environmental justice. In addition, a socioscientific approach framed by environmental justice motivates and empowers students in a way that a STEM approach alone cannot. Based on our instructional strategies and research findings, we make recommendations for transforming environmental science instruction.

Keywords: Environmental justice, environmental science, socioscientific issues, student motivation

Science teachers in 26 states have begun to implement the Next Generation Science Standards (NGSS), which promise to motivate students through the practice of science (Achieve Inc., 2013). The NGSS reflect the STEM movement, which aims to build a strong workforce that will usher in prosperity and the promise of a more secure nation. However, a focus on STEM may exclude the sociopolitical aspects of science that could encourage students to develop a sense of civic responsibility (Zeidler, 2014). Environmental issues including water pollution, pipeline construction and climate change have proven to be politically-charged scientific issues. Rather than prepare our students for the future, we considered preparing high school environmental science students for immediate action as engaged citizens in a contentious and confusing society.

In an ongoing inquiry, we explore the potential for environmental justice to motivate high school environmental science students. In four sections of high school Environmental Science, we measured student dispositions before and after an introductory unit that highlighted environmental justice in socioscientific issues (SSIs), which Sadler, Chambers, and Zeidler (2004) describe as "social dilemmas with conceptual ties to science" (p. 387). Herein, we explore the major concepts that emerged from student stories told during interviews that shed light on their learning experiences in the course, illuminating changes in their motivation to learn science. Furthermore, we include recommendations for environmental science teachers to infuse socioscientific lessons with environmental justice, to encourage students to develop their voices for environmental advocacy and sociopolitical action.

Lesson Design

When measuring student dispositions, we found that students valued morals in environmental decision-making. Therefore, we enhanced our problem-based curriculum with socioscientific approach that required students to reflect on their worldview and develop their environmental ethic. The curricular approach required instructional strategies beyond traditional science education pedagogy, yet remained student-centered and inquiry-based. We encouraged students to ask questions and use evidence to draw conclusions. SSIs served as "phenomena", defined by the NRC (2012) as observable events that students can explain and make sense of by using the three dimensions of the NGSS (Disciplinary Core Ideas, Science and Engineering Practices, and Crosscutting Concepts).

We justify a socioscientific approach by rejecting the assumption that all scientists do science in the same way and are motivated by the same things. Therefore, we applied the NRC's (2012) broad description of science practices, including critique. Through discussion, discourse, and reflective writing, students explored their positions on issues ranging from pipelines to food deserts, based on their worldviews as well as scientific evidence. By reflecting on their worldviews and ethics, students developed the attitudes that predispose them to environmental literacy, which considers dispositions that include attention to equity, a willingness to take action, personal responsibility, with a basis in concern for other people and other societies (Hollweg, et al., 2011). We aligned the lessons to the standards that best reflect our approach (see Appendix E).

As the unit began, students investigated the three main environmental ethics (anthropocentrism, biocentrism, and ecocentrism) and included a lesson on Dr. Martin

Luther King, Jr.'s influence on the environmental movement. We focused on the Dakota Access Pipeline protests in North Dakota, which reached a fever pitch during this unit, realizing that renewable energy resources was the focus of a future curricular content. In fact, environmental justice encompassed each environmental issue the students brought up, reflecting a pattern in which environmental problems connected to greater societal ills mired in inequity and discrimination. The unit culminated in a group project in which students designed a community garden in a food desert. Students expressed pride in applying the dispositions and skills they had developed to make a difference in the lives of others, paving the way for units on biodiversity, urbanization, water pollution, energy sources, and climate change that would leverage a justice-based approach to sustainability.

Become the Change Agent You Want Your Students to Be

Science teachers may serve as mentors for civic participation, rather than mere technicians and implementers of educational standards. Consciousness of environmental problems and concern about their impacts on people are hallmarks of environmental literacy (Hollweg, Taylor, Bybee, Marcinkowski, McBeth, & Zoido, 2011). We contend that teachers should act as ambassadors of eco-consciousness, and proponents of environmental justice. An environmental science classroom built on a socioscientific approach becomes more democratic through both inquiry and discourse.

This transformation starts with the teacher. Science teachers tend to avoid controversial topics because they do not know how to teach them (Gayford, 2002). Their ambivalence disengages students when we perpetuate the traditional view that science is value-free. Our students wanted teachers to express their opinions in the classroom to

show that they care not only about the material they are teaching, but also the issues that they present. Therefore, we recommend standing up for the environment, and for the people who at disproportionate risk of being harmed or displaced by environmental problems.

A socioscientific approach requires an understanding of, and sensitivity to, students' backgrounds. Teachers must respect and incorporate students' worldviews to demonstrate how to arrive at opinions based on argumentation and dispositions. Our students proposed that science teachers model decision-making through argumentation. SSIs enhance these skills by highlighting interactions between environmental problems and societal troubles. As environmental justice invokes diversity and inclusivity, students may develop a unified front towards environmental stewardship that may inspire civic participation. Therefore, teachers who design lessons around SSIs facilitate authentic inquiry-based learning in an increasingly democratic sense. Teaching environmental science thus requires a critical lens that considers culture, politics, and ethics. Social studies and English teachers provided valuable insight into leading discussions and debates that do not usually occur in science classrooms. Relevance of SSIs increased through interdisciplinary collaborations.

Invite Change Agents into Your Classroom

Our students admired scientists as change agents who deserve the resources to conduct their research and a voice in policy making. One student declared, "If they have extensive of knowledge of what's going on, they can definitely help." In their eyes, scientists monitor environmental health, as well as provide solutions. Through their contemporary vision of scientists, they connected societal problems to environmental

challenges as lessons evolved into critiques of inequity, racism, discrimination, and oppression, with environmentalists bolstered by scientific knowledge. Environmental justice proved to be a foundation for their thinking when they learned how the civil rights movement of the 1960s advanced environmental protection as a human rights issue.

Teachers may act as role models who reflect both science and activism by enacting an ecocentric stance both in and out of the classroom. Teachers may invite guest speakers into the classroom to offers students the chance to connect with environmentalists and other activists. Through TED Talks and online research, our students "met" activists who confront problems like food deserts, access to nature, and the presence of waste management plants that plague the urban and suburban neighborhoods that our students were familiar with.

Students may build confidence when they realize that they can participate in change efforts. Confidence and motivation reinforce each other when students can see themselves in the work they study (Oyserman & Destin, 2010). Footage of the Dakota Access Pipeline protests inspired conversations about the extent to which students would participate; daily updates of the intensifying protests fueled class dialogues. Lessons became transformative when students can identify with, and as, stakeholders.

Position Students as Change Agents

Through environmental justice, students confronted the social impact of environmental problems. Advocates of environmental justice contend that environmental problems affect marginalized populations more than privileged groups. SSIs can provoke civic engagement and other forms of "meaningful involvement" promoted by

environmental justice (EPA, 2017). One resolute student described expanding STEM practices to include more pressing concerns:

> If you can only teach about how it is being built, I don't think that would be fair, because I feel like they should be able to know what's going on in their community. If something was being built in my community, say there was a new water tower being built two streets from my house, I would want to know...how it's being built and why.

Transcending the design of technological solutions through engineering practices, science becomes transformative when students ask why a problem exists in the first place.

Learning how to write environmental policies enhanced students' capacity to propose solutions. After researching a local environmental problem, each student wrote to a nearby legislator to explain the science behind an environmental problem, and offer legitimate solutions. Students expressed genuine concern for their topics, which included pollution-induced asthma, access to nature, and the waste treatment plants in their neighborhoods. By exploring these phenomena, students were also authentically engaged in their communities.

Empowering Science Students with Environmental Justice Itself

Eventually, the classroom environment transforms thanks to student participation that mirrors civic engagement, as our pedagogy empowered students to become change agents themselves. One student declared our class "the most outgoing and forward class I've had for science so far." Schindel Dimick's (2012) framework for social justice science education, which includes three types of mutually reinforcing empowerment, validates our approach.

First, social empowerment emerged through the development of a supportive, and inclusive classroom in which students felt safe and confident in expressing themselves, (and supported each other in doing so). Students realized that their voice could be a strong force for equity and inclusion. Second, students became politically empowered. One student declared, "Environmental science isn't just about the plants, it's about you know, different political standing." Her classmates critiqued inequities surrounding environmental pollution and access to environmental resources. They sided with the Sioux people in their efforts to protect their water and sacred lands and questioned the inequities suffered by African Americans in cities like Camden, NJ, and Los Angeles. Finally, academic empowerment was evident in the development and application of knowledge and skills that support student success in all settings. Students routinely referred to concept maps they created to demonstrate the interconnectedness and interrelatedness of Earth's spheres, as those phenomena implicated societal problems. Student integrated course content with history class. Written and oral exercises required skills developed language arts class. One student explained, "Science can be anything from political, to social, to environmental, to biology, about the stars." At this point, the overlap with political empowerment became apparent.

As the unit ended with a case study on food deserts, the emergence of a contest to build a community garden demonstrated the transformation of the classroom, and the mutual reinforcement of the three forms of empowerment. Learning experiences had proved to be truly authentic, as the learning involved complex, realistic tasks that can be applied outside the classroom (Frey, Schmitt, & Allen, 2012). Motivated to effect

positive change, students could take the reins of the lesson and curriculum, and take the learning out of the classroom to effect positive change.

Environmental Science in the NGSS Era

Students suggested that socioscientific issues should be the focus of a classroom that implements STEM practices, as prescribed by the NGSS, because a solely STEM approach did not appeal to them. One student claimed that traditional assignments offer too much opportunity to disengage. He pictured kids opting out of learning:

> I'm not going to build a bridge; I'm not going to be an engineer. I'm not even going to live near a river where there is a bridge...I'm not gonna do the lab. I don't need to do the lab. Why should I do a lab?

By engaging students in issues that matter to them, they have the opportunity to express themselves, and to participate authentically through immediate civic action rather than an eventual STEM career. That same student, once empowered, expressed concerns about, and responsibility for, his community's water quality:

> I definitely went home and filled my glass with water and looked in it, and was like, "Is there lead in there?" I think I will [test it], just for the sake of other people...I don't want to have that problem so I definitely would test the water just to make sure that it's safe.

His transformative attitude transcends the NGSS' technocentric approach, which values scientific and technological solutions to global challenges like sustainability (Feinstein & Kirchgasler, 2014). Science education, environmental or otherwise, may not be complete without considering social and ethical dimensions of the phenomena students study, especially when taught in isolation. If environmental science is concerned with the

interconnectedness and interrelatedness of Earth's systems, it behooves us to realize that the environment is no longer a natural system that humans have impacted, but rather a social construct that includes natural systems (Hodson, 2003).

Conclusion

When we talk about "testing the waters," we can begin by sampling local water for impurities, as one student imagined. However, we may consider taking risks that motivate students by elevating the NGSS. Our research demonstrates the transformative power of including social justice education in science classrooms. Furthermore, we would not restrict this approach to environmental science: We suggest using socioscientific issues in physics, biology, and chemistry, such that teachers connect practices across disciplines. A sociopolitical approach may motivate all students in a way that encourages holistic education that is relevant, realistic, and crucial.

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Appendix A

Survey Protocol

Environmental Justice in Environmental Science

Please consider the following statements thoughtfully and sincerely. Respond on a scale of 1 to 10, with 1 indicating complete disagreement and 10 indicating complete agreement. Your participation is voluntary, and will in no way impact your grade, your disciplinary record, or your teacher's opinion of you. Thank you for participating.

* Required

1. **1. Threats to the environment can affect me.** *
   Mark only one oval.

	1	2	3	4	5	6	7	8	9	10	
Completely disagree	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯	Completely agree

2. **2. I am optimistic about our potential to solve environmental problems during my lifetime.** *
   Mark only one oval.

	1	2	3	4	5	6	7	8	9	10	
Completely disagree	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯	Completely agree

3. **3. Science and technology can solve most of our environmental problems** *
   Mark only one oval.

	1	2	3	4	5	6	7	8	9	10	
Completely disagree	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯	Completely agree

4. **4. I am willing to make sacrifices to help solve environmental problems.** *
   Mark only one oval.

	1	2	3	4	5	6	7	8	9	10	
Completely disagree	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯	Completely agree

5. **5. Solving environmental problems should not be left to the experts.** *
   Mark only one oval.

	1	2	3	4	5	6	7	8	9	10	
Completely disagree	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯	Competeley agree.

6. **6. In general, I am optimistic about the future.** *
Mark only one oval.

	1	2	3	4	5	6	7	8	9	10	
Completely disagree	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯	Completely agree

7. **7. Environmental problems can be solved without significant changes to our way of living.** *
Mark only one oval.

	1	2	3	4	5	6	7	8	9	10	
Completely disagree	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯	Completely agree

8. **8. Consider different countries around the world. The same environmental problems have different impacts on all countries.** *
Mark only one oval.

	1	2	3	4	5	6	7	8	9	10	
Completely disagree	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯	Completely agree

9. **9. Consider communities within the same city, or within the same state. Environmental problems affect some communities in the same state or city more than others.** *
Mark only one oval.

	1	2	3	4	5	6	7	8	9	10	
Completely disagree	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯	Completely agree

10. **10. Considering people within any given community. Environmental problems affect some people more than others.** *
Mark only one oval.

	1	2	3	4	5	6	7	8	9	10	
Completely disagree	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯	Completely agree

11. **11. Policy makers (such as politicians) dealing with environmental problems should listen to scientists.** *
Mark only one oval.

	1	2	3	4	5	6	7	8	9	10	
Completely disagree	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯	Completely agree

12. **12. Community leaders dealing with environmental problems should listen to scientists in order to develop proper solutions.** *

Mark only one oval.

	1	2	3	4	5	6	7	8	9	10	
Completely disagree	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯	Completely agree

13. **13. Environmental problems connect to economic problems in society.** *

Mark only one oval.

	1	2	3	4	5	6	7	8	9	10	
Completely disagree	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯	Completely agree

14. **14. Environmental problems connect to social problems in society.**

Mark only one oval.

1	2	3	4	5	6	7	8	9	10
◯	◯	◯	◯	◯	◯	◯	◯	◯	◯

15. **15. it is important to consider morals when solving environmental problems.** *

Mark only one oval.

	1	2	3	4	5	6	7	8	9	10	
Completely disagree	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯	Completely agree

16. **(Optional) Please enter your full name, especially if you wish to participate in further research.**

17. **Do you identify as a male or female?** *

Mark only one oval.

- ◯ Female
- ◯ Male

Appendix B

Interview Protocol

1. How have you enjoyed Environmental Science so far?
2. Tell me about a lesson that you enjoyed most.
3. Think about the three environmental perspectives we have studied: anthropocentrism, biocentrism, and ecocentrism. Describe how your attitude towards the environment has developed or changed in light of environmental science during this course.
4. Think of an environmental problem. Describe how that problem affects different people more than it affects others. How does that make you feel?
5. What do you think of people who tackle problems in their communities?
6. Describe how you envision your participation in your community as you grow up.
7. Tell me about your plans for after high school. Describe lessons that have had an impact on your plans, and how you worked them into your personal vision.
8. Describe the future based on what you have learned about environmental problems.

Appendix C

Changes in Student Dispositions

Mean responses on survey of student dispositions before and after instruction, where 0 is complete disagreement and 10 is complete agreement with the statement. Pretest N = 70. Post-test N=30, *p< .05, **p< .01, ***p< .000

Appendix D

Frequency Distribution of Responses on Pre-Intervention Survey

		Ordinal Response										
Survey Item		1	2	3	4	5	6	7	8	9	10	Total
Threats to the environment can affect me	n	1	0	1	0	2	1	4	3	1	17	30
	(%)	3.33	0	3.33	0	6.67	3.33	13.3	10.0	3.33	56.6	100
I am optimistic about our potential to solve environmental problems in my lifetime	n	1	0	1	2	7	3	4	8	3	1	30
	(%)	3.33	0	3.33	6.67	23.3	10.0	13.3	26.7	10.0	3.33	100
Science and technology can solve most of our environmental problems	n	1	2	1	0	7	2	10	4	1	2	30
	(%)	3.33	6.67	3.33	0	23.3	6.67	33.3	13.3	3.33	6.67	100
I am willing to make sacrifices to help solve environmental problems	n	2	0	1	3	9	2	2	3	2	6	30
	(%)	6.67	0	3.33	10.0	30.0	6.67	6.67	10.0	6.67	20.0	100
Solving environmental problems should not be left to the experts	n	5	0	3	2	4	1	1	4	4	6	30
	(%)	16.7	0	10.0	6.67	13.3	3.33	3.33	13.3	13.3	20.0	100
In general, I am optimistic about the future	n	1	0	2	1	8	1	5	5	4	3	30
	(%)	3.33	0	6.67	3.33	26.7	3.33	16.7	16.7	13.3	10.0	100
Environmental problems can be solved without significant changes to our way of living	n	6	4	0	2	6	4	2	4	2	0	30
	(%)	20.0	13.3	0	6.67	20.0	13.3	6.67	13.3	6.67	0	100

The same environmental problems have different impacts on different countries	n	2	0	0	3	5	2	5	4	4	5	30
	(%)	6.67	0	0	10.0	16.6	6.67	16.6	13.3	13.3	16.7	100
Environmental problems affect some communities in the same state or city more than others	n	2	0	2	0	2	3	8	4	3	6	30
	(%)	6.67	0	6.67	0	6.67	10.0	26.6	13.3	10.0	20.0	100
Environmental problems affect some people in the same community more than others	n	2	0	1	1	3	1	6	7	1	8	30
	(%)	6.67	0	3.33	3.33	10.0	3.33	20.0	23.3	3.33	26.7	100
Policy makers dealing with environmental problems should listen to scientists	n	1	0	0	1	5	6	3	5	5	4	30
	(%)	3.33	0	0	3.33	16.7	20.0	10.0	16.7	16.7	13.3	100
Community leaders dealing with environmental problems should listen to scientists	n	1	0	1	4	2	2	5	4	5	6	30
	(%)	3.33	0	3.33	13.3	6.67	6.67	16.7	13.3	16.7	20.0	100
Environmental problems connect to economic problems in society	n	1	0	1	1	3	5	4	7	3	5	30
	(%)	3.33	0	3.33	3.33	10.0	16.67	13.3	23.3	10.00	16.67	100
Environmental problems connect to social problems in society	n	1	1	0	0	4	2	6	4	3	9	30
	(%)	3.33	3.33	0	0	13.3	6.67	20.0	13.3	10.0	30.0	100
It is important to consider morals when solving environmental problems	n	0	0	0	3	2	5	4	4	3	9	30
	(%)	0	0	0	10.0	6.67	16.7	13.3	13.3	10.0	30.0	100

Frequency of responses on survey of student dispositions before intervention, where 0 is complete disagreement and 10 is complete agreement with the statement.

Appendix E

Frequency Distribution of Student Responses on Post-Intervention Survey

		Ordinal Response										
Survey Item		1	2	3	4	5	6	7	8	9	10	Total
Threats to the environment can affect me	n	1	0	1	0	2	1	4	3	1	17	30
	(%)	3.3	0	3.3	0	6.67	3.33	13.3	10.0	3.33	56.6	100
I am optimistic about our potential to solve environmental problems in my lifetime	n	1	0	1	2	7	3	4	8	3	1	30
	(%)	3.33	0	3.33	6.67	23.3	10.0	13.3	26.7	10.0	3.33	100
Science and technology can solve most of our environmental problems	n	1	2	1	0	7	2	10	4	1	2	30
	(%)	3.33	6.67	3.33	0	23.3	6.67	33.3	13.3	3.33	6.67	100
I am willing to make sacrifices to help solve environmental problems	n	2	0	1	3	9	2	2	3	2	6	30
	(%)	6.67	0	3.33	10.0	30.0	6.67	6.67	10.0	6.67	20.0	100
Solving environmental problems should not be left to the experts	n	5	0	3	2	4	1	1	4	4	6	30
	(%)	16.7	0	10.0	6.67	13.3	3.33	3.33	13.3	13.3	20.0	100
In general, I am optimistic about the future	n	1	0	2	1	8	1	5	5	4	3	30
	(%)	3.33	0	6.67	3.33	26.7	3.33	16.7	16.7	13.3	10.0	100
Environmental problems can be solved without significant changes to our way of living	n	6	4	0	2	6	4	2	4	2	0	30
	(%)	20.0	13.3	0	6.67	20.0	13.3	6.67	13.3	6.67	0	100
The same environmental problems have different impacts on different countries	n	2	0	0	3	5	2	5	4	4	5	30
	(%)	6.67	0	0	10.0	16.6	6.67	16.6	13.3	13.3	16.67	100
Environmental	n	2	0	2	0	2	3	8	4	3	6	30

problems affect some communities in the same state or city more than others	(%)	6.67	0	6.67	0	6.67	10.0	26.6	13.3	10.0	20.0	100
Environmental problems affect some people in the same community more than others	n	2	0	1	1	3	1	6	7	1	8	30
	(%)	6.67	0	3.33	3.33	10.0	3.33	20.0	23.3	3.33	26.67	100
Policy makers dealing with environmental problems should listen to scientists	n	1	0	0	1	5	6	3	5	5	4	30
	(%)	3.33	0	0	3.33	16.67	20.00	10.0	16.67	16.67	13.33	100
Community leaders dealing with environmental problems should listen to scientists	n	1	0	1	4	2	2	5	4	5	6	30
	(%)	3.33	0	3.33	13.3	6.67	6.67	16.67	13.3	16.67	20.00	100
Environmental problems connect to economic problems in society	n	1	0	1	1	3	5	4	7	3	5	30
	(%)	3.33	0	3.33	3.33	10.0	16.67	13.3	23.3	10.00	16.67	100
Environmental problems connect to social problems in society	n	1	1	0	0	4	2	6	4	3	9	30
	(%)	3.33	3.33	0	0	13.3	6.67	20.0	13.3	10.0	30.0	100
It is important to consider morals when solving environmental problems	n	0	0	0	3	2	5	4	4	3	9	30
	(%)	0	0	0	10.0	6.67	16.67	13.3	13.3	10.0	30.0	100

Frequency of responses on survey of student dispositions following intervention, where 0 is complete disagreement and 10 is complete agreement with the statement.

Appendix F

Codebook

Table 3.
Final codes for RQ3

Theme	Definition	Sample quotation
1. Student perceptions of the "environment."		
Outdoors	Students identify the outdoors as the environment, especially gardens and parks	"We live in a suburb area; that's our environment. We have trees, we have natural areas we can go to, we have parks. There's natural parks, dog parks" (Andrew)
Comprised of commodities	Students recognize the goods and services natural systems provide	"I wasn't even sure of my local water supply. If there is a problem, and I am not even 100% sure on what is actually going on with that." (Hugo)
Damaged	Students see ecosystems and even the entire natural world as ruined due to human impact	"The environment is dying as we speak" (Katrina)
2. The role of scientists in society		
Change agents	Students see scientists as valuable citizens who seek knowledge and understand environmental problems	"If they are the ones studying it, I feel that they know what is best, like how to fix the lead, why there is too much lead" (Ivan)
Policy makers	Students suggest that scientists are part of the policy process	"I mean if they have extensive knowledge of what's going on, they can definitely help. Maybe they shouldn't directly write the statements, but they can

			definitely put their inputs into them" (Andrew)
	Emotional voices for action	Students recognized scientists' emotions can influence their opinions, evoking an ethic of care	"They [scientists] can tell them [policy makers] how they feel and how they can improve what's going" (Andrew)
3.	Empowerment through a sociopolitical approach		
	Academic	Students recognized that SSIs are relevant and require higher-level thinking and skills developed in other content areas	"It makes us start thinking and makes is process things faster. It makes us conclude our opinions, bring in more opinions from other people and then think of more and more opinions and solutions that we can probably conjure up" (Dayle)
	Social	Student notice how discourse and collaboration create a more energetic classroom	"This has been the most forward, most outgoing and forward class I've had for science so far and it's had the most effect. We talk to each other, but at the same time we do work. The projects we do: talking is a huge part" (Hugo)
	Political	Students practice civic engagement as they learn academic content	"Us as a group. like if I was to get our community to actually (they don't have to do research), but like, could inform them and show them like the bad things that can happen with that pipeline being built, and with you know, it being close to use, how it can affect us...We come together, protest..." (Dayle)

4.	There is freedom in doing science through SSIs		
	Engagement beyond STEM alone	Students perceive STEM as career driven and impersonal, and based on content they are already disinterested in	"Kids sitting in the back of the class: 'Yeah, I'm not gonna do the lab. I don't need to do the lab. Why should I do a lab?" (Ivan)
	Connection to the humanities	Students notice that they encounter similar topics in other courses, and appreciate the role of discussion and debate in science class	"If we incorporate history into science, and you say like well, you know, in 1900 or 1800 you know, whatever it is, something happened and this was the cause. It be like, woo! Now we see it progressing back to what happened." (Katrina)
	Personal connection	Students want to understand themselves and be able to express themselves.	"Environmental justice is important, I do think, that's important because it fuels, it helps them like, basically, 'Holy crap! There are actually people trying to help them!' It makes the kids especially think more and more like these people, who are actually doing something." (Katrina)

Appendix G

Learning Activities and Aligned NGSS Standards

Standards **HS-ESS3 Earth and Human Activity** **HS-ETS1 Engineering Design**		
Performance Expectation(s) *The materials/lessons/activities outlined in this article are just one step toward reaching the performance expectations listed below.* **HS-ESS3-1,4. Evaluate or refine a technological solution that reduces impact of human activities on natural systems** **HS-ETS1-3. Evaluate a solution to a real-world problem based on prioritized criteria and trade-offs that account for a range of constraints, including cost, safety, reliability, and aesthetics, as well as possible social, cultural, and environmental impacts**		
Dimension	**Name and *NGSS* code/citation**	**Specific Connections to Classroom Activity**
Science and Engineering Practices	**Asking Questions and Defining Problems** • Ask questions that arise from careful observation of phenomena, or unexpected results, to clarify and/or seek additional information (HS-ESS3-4; HS-ETS1-3) **Engaging in Argument from Evidence** • Respectfully provide and/or receive critiques on scientific arguments by probing reasoning and evidence and challenging ideas and solutions, responding thoughtfully to diverse perspectives, and determining what additional information is required to resolve contradictions (HS-ESS3-4; HS-ETS1-3)	Students viewed a TED Talk by Ron Finley, who develops community gardens in Los Angeles. They completed graphic organizers to display the factors that his mission addresses Students debated the pros and cons of the Dakota Access Pipeline and made protest posters to declare their positions based on evidence Students wrote environmental ethics statements after exploring their worldviews and completing a survey on their dispositions about nature and society Students researched a local

	• Construct, use, and/or present an oral and written argument or counterarguments based on data and evidence (HS-ESS3-4; HS-ETS1-3) • Evaluate competing design solutions to a real-world problem based on scientific ideas and principles, empirical evidence, and/or logical arguments regarding relevant factors (e.g. economic, societal, environmental, ethical considerations (HS-ESS3-4; HS-ETS1-3)	environmental issue and, after learning about the policy process, wrote letters to local legislators
Disciplinary Core Ideas	**ESS3.A: Natural Resources** • Resource availability has guided the development of human society. (HS-ESS3-1,4) **ETS1.B Developing Possible Solutions** • When evaluating solutions it is important to take into account a range of constraints include cost, safety, reliability, and aesthetics and to consider social, cultural, and environmental impacts (HS-ESS3-4, HS-ETS1-3)	The students performed a simulation of the Tragedy of the Commons using goldfish crackers. Students collaborated to design community garden, based on specific constraints, starting with choice of crops
Crosscutting Concept(s)	**Patterns** • Different patterns may be observed at each of the scales at which a system is studied and can provide evidence for causality in explanations of phenomena (HS-ESS3-4, HS-ETS1-3) **Cause and Effect** • Changes in systems may	Students made concept maps to demonstrate the interconnectedness and interrelatedness of natural systems, and later including societal factors. Students debated whether pipeline construction represents an issue of

	have various causes that may not have equal effects (HS-ESS3-4, HS-ETS1-3)	social justice or environmental justice, to explore the intersection between the two concepts.