The Impacts Of Classroom Stem¬-Themed Environmental Investigations On Middle School Environmental Literacy

Megan Alece Heitkamp
Hamline University, mheitkamp01@hamline.edu

THE IMPACTS OF CLASSROOM STEM-THEMED ENVIRONMENTAL INVESTIGATIONS ON MIDDLE SCHOOL ENVIRONMENTAL LITERACY

by

Megan A. Heitkamp

A capstone submitted in partial fulfillment of the requirements for the
degree of Master of Arts in Education: Natural Science and Environmental Education.

Hamline University

Saint Paul, Minnesota

December 2016

Primary Advisor: Trish Harvey
Secondary Advisor: Kelly Prusak
Peer Reviewer: Anne Satori

ACKNOWLEDGEMENTS

I would like to thank my committee members for their continued support and feedback throughout this researching and writing process. I simply could not have done it without each of you!

I extend gratitude to the MSELS authors: Hungerford, Volk, McBeth and Bluhm (2006), for allowing me to use their research tool in this project.

My students receive an extra special thanks; they always push me to find new ways of connecting all learners to the natural world.

My family consistently supports my adventures in learning, and I am grateful for their constant encouragement, time and cheerleading; it all started with taking family vacations as far as our minivan could take us and setting up our tent in some of the most beautiful and influential places!

To Stevie, thank you for your energy, patience and understanding. Your support has been one of the key influences in my success. To our little Junebug, may you forever enjoy being in nature, finding critters, asking questions, getting muddy and exploring!

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

CHAPTER ONE

INTRODUCTION

Introduction

What do we hope for our students? What do we hope for our world? These two questions are essential to my adventures as a science teacher. As students navigate their way through learning experiences, I hope they become fascinated with the natural world surrounding them. Instilling a passion for inquiring how the leaves change color or exploring why bacteria act as nature's recyclers place students in the active mindset of environmental literacy. Students who acquire a passion for learning by posing questions and investigating solutions are likely to encounter opportunities to further analyze the nature of problems and test different solutions to environmental problems. This is the heart of environmental literacy and the topic of my research: *How does integrating STEM-themed environmental investigations in the middle school classroom impact environmental literacy?*

In chapter one, I share the seeds and growing conditions that brought me to this area of focus; so many accomplishments and challenges shaped the landscape of what I find most valuable in formal teaching and environmental education. In addition, I examine the impacts of this research on various stakeholders, including students, families, schools and school districts. It is my hope that this research opens a new window for other dedicated teachers hoping to help students cultivate an intensity for inquiry and problem-solving using authentic environmental issues.

Planting the Seed

I grew up traveling national and state parks; my family and I would load up the minivan, filling it with essentials for our car-camping adventures. This was second nature to me: summers spent putting distance between my hometown and our national and state park checklist. It was not until I was in high school that I realized this was not a common tradition for my peers, and I was saddened at how many of my friends had not yet seen the Grand Canyon, fossils at Dinosaur National Monument, Cadillac Mountain in Acadia or Teddy Roosevelt's playground in North Dakota. I was not judging my friends, because I understood that many factors control whether families can travel. I recognized that my camping-filled summers were not ideal travel itineraries for all families. However, my early travels in the kid carrier, a trusty faded Kelty, influenced so many personal and professional parts of me. Not only did I enjoy getting my stamps in my national park passport, but I also enjoyed how exploring the wildlands changed me for the better. These experiences fostered my passion for sharing nature with others.

During high school, I began work as a summer camp naturalist sharing nature and science with teenagers. As I planned lessons and experiences, I observed a distinct difference in how campers responded to different teaching methods. I examined inside teaching versus outdoor teaching and observed lectures filled with scientific facts versus mini-lessons mixed with experimentation. When I provided a learning environment where exploration and questioning was expected, engagement drastically increased. One example includes Setton Sits where campers sit quietly in nature recording observations, creating sound maps and writing questions. This experience, coupled with other teaching opportunities at nature centers and adventure-based organizations, illustrated the importance of learners feeling connected to their natural world through inquiry and hands-on, minds-on experiences. I realized how changing learning structures influenced the depth of learning and I realized the power of environmental education.

Spreading Roots

When I began my career as a middle school science teacher, I anticipated that my middle school students would respond to instructional strategies just as my campers did; I was wrong. Entering the formal education world was a game-changer and within a few years, I had the opportunity to transition from a traditional middle school to a STEM-themed magnet middle school. Based on my experience at a traditional school, students generally seemed disconnected with their natural surroundings and even the learning process. Questions were being asked and it was challenging to motivate learners to discover their own answers or pose additional questions of their own. Time was spent meeting learning targets instead of engaging in authentic problem-solving. Using a STEM teaching lens addresses many of these concerns, including appealing students to think in-depth about real-world problems while meeting learning goals. Inquiry and investigations become the cornerstone of this STEM pedagogy and curriculum returns students back into the driver's seats of their own education. With this adapted focus, my passion and curiosity reignited, I spent more time developing strategies to immerse students in the cycles of the Earth and venture outside. Over time, I observed a dynamic shift in learning because students were posing their own questions to guide their own learning both in and out of the classroom.

After a few years in the science classroom, I was hired as a Teacher-Ranger-Teacher through the National Park Service spending a summer developing curriculum. As an interpretive ranger, I assisted visitors in planning their adventures and expanded the lessons plans to include more geology, paleontology, hands-on learning and authentic problems for the area like water wars. This opportunity enabled me to interact with a diverse audience at Dinosaur National Monument on the Colorado/Utah border and helped me understand the unique ways in which people approach science and environmental topics. People see different value levels in nature and science. When I developed curriculum regarding paleontology, I thought thoroughly about how audiences perceive the value of fossils. Some monument visitors simply asked, “Where are the fossils?” These visitors were not necessarily interested in how or why there were unique fossils in this area; they wanted to see them and move on. Other visitors were interested in seeing the fossils and learning about the scientific and cultural history of the area which extends beyond fossil hunting. I recognized the importance of meeting my audiences where they started and keeping a clear vision of the varying levels of visitors’ knowledge and experience as they explored the monument.

At the STEM school, a mentor teacher asked me to help her facilitate an after school GEMS (girls in engineering, math and science) club. We designed hands-on, science activities for pre-teen, female students. The goal was to promote a growth mindset regarding science among middle-level girls and activities ranged from growing crystals to heart dissections to fractals. This club provided me with an opportunity to merge STEM with nature science, and I practiced planning environmental education activities for middle school learners.

One learning experience was memorable in assisting me to further explore “green” STEM and environmental literacy. On a summer afternoon, our mission was to explore the impact of earthworms on a local habitat. The girls were surprised to learn that many earthworm species are invasive and negatively impact forest ecosystems in Minnesota. It was a relevant and popular area of research that I recently learned about through a professional development opportunity at our local National Wildlife Refuge. We discussed and planned different procedures to collect the earthworms at the park, which was a short walk from our school. At first, the girls were reluctant to touch the earthworms once they were extracted from the soil (using a mustard and water mixture); however, soon earthworms were popping up all over the place and laughter erupted as they grabbed earthworms with tweezers, placing them under hand lenses for identification. Participant engagement was high and the girls were actively learning and experiencing. This was what my teaching dreams were made of.

Adding Leaves

A final classroom observation truly brought me to where I am today. My students were able to understand why environmental problems happen and how these problems impacted the natural cycles of the Earth; however, they struggled with posing solutions to local environmental problems. For example, students were able to identify that climate change had negative impacts on ecosystems; they were challenged by identifying the localized impacts of this environmental problem and toiled to determine action steps to take. Research by McBeth and Volk (2009), two environmental literacy experts, indicated that environmental literacy is a spectrum with students first engaging with the cycles of the Earth working towards understanding the interconnectedness of these cycles and on the opposite end of the spectrum, students problem-solve and commit to act towards improving the environmental world surrounding them. Bridging the gap between general science or environmental knowledge and problem-solving is an elusive challenge for middle school students. I have speculated that because students are not placed into learning experiences where it is expected they problem-solve authentic issues, this skill goes undeveloped. Over time, I have experimented through different lenses, in hopes of reaching students and bringing them to this higher level of environmental literacy. I have not necessarily found a teaching method that can reach across this gap. It is my hope that using STEM-themed investigations to solve an environmental problem can serve as the bridge needed to connect environmental knowledge to awareness and to problem-solving.

Sharing Seeds with Others

During my work as an undergraduate student in environmental education, we spent great time reviewing the Tbilisi Declaration (1978) organized by the UNESCO and UNEP. One significant part of this document sparked my passion for using STEM to improve environmental literacy. The declaration asked that environmental education "emphasize the complexity of environmental problems and thus the need to develop critical thinking and problem-solving skills" (p. 27). Both critical thinking and problem-solving skills are essential for student success in our dynamic world. Students are dynamically shaped when they are asked to solve real world problems, these problems might impact them currently or in the future. Students engage at high levels when they are asked to creatively unlock solutions and collaborate with classmates to determine these resolutions.

STEM and environmental literacy concepts ask students to think both broad (systems of the Earth) and narrow (their local communities and environments). Beyond the science, students need to process the impacts of problems on the social, economic and natural systems of the world (National Research Council, 2011). When students consider local and global issues, they develop a capacity to become engaged citizens who can problem-solve issues of the future (Arzy-Mitchell, 2013; Harmer & Cates, 2007). My research helps qualitatively and quantitatively measure the effectiveness of using a STEM teaching lens to influence the environmental literacy of middle school students.

STEM-themed lesson plans, curricular resources and school structures are ever increasing as partnerships between governments, educational entities, and companies form to build skills for today's learners (Basham, Israel, & Maynard, 2010, p. 10). Parents are enthusiastic in the idea of STEM and positively view the learning environment that is created with inquiry as a firm cornerstone; furthermore, parents play a significant role in encouraging STEM education (Dorie, Jones, Pollock & Cardella, 2014). Combining STEM and environmental literacy prepares students for a variety of job opportunities by improving their investigative skills and calling students to learn about their influence on the environment (Honey, Pearson & Schweingruber, 2014). The philosophy of STEM schools is often attractive to local businesses and it lends itself to opportunities for school and community partnerships. STEM-based learning hopes to assist in preparing today's students for the careers of the future. These careers reach beyond the science and technology sector and venture into career areas that employ innovative and creative thinking (Mueller, 2014, p. 2). Focusing on environmental engineering problems at a local level can show students new potential career paths where they will in fact improve their community and the Earth (Breiner et al., 2012, p. 5; Sanders, 2009, p. 21).

Because there are multiple focuses of environmental literacy, problem-solving being just one, there are many connection points for other science teachers that are looking for ways to cultivate environmental literacy in their students. Through networking with other teachers in formal classrooms, these teachers have identified that it can be stressful adding environmental education initiatives because some teachers feel that they need to be going outside each day. Taking students outside can be an important part of students developing a sense of their natural surroundings and appreciation for the cycles of nature; however, there are many more components to developing environmental literacy in students. Classroom-based teachers face a long list of expectations that change frequently throughout the year and such high value is placed on standardized test scores or other means of data collection. Inquiry-based learning initiatives such as integrated STEM ask students to understand concepts, knowledge and issues at a variety of cognitive levels (Witt & Ulmer, 2010). Through this research, I hope to demonstrate that a wider variety of teaching pedagogies (including STEM) also positively influence students' journeys toward becoming environmentally literate and further developing inquiry skills.

With the recent passage of the Every Student Succeeds Act, Congress has placed a prioritized value on STEM education, environmental literacy and environmental education (Bodor, 2015). If there is a positive correlation between using STEM to solve environmental problems and improving environmental literacy, this evidence and research could help convince school districts to place a higher value on environmental education and programs that develop students' environmental literacy. This research could assist teachers, curriculum coordinators and other influential leaders to develop programs using new avenues of funding through the Every Student Succeeds Act. Industry leaders in STEM fields may partner with more schools, bringing authentic learning experiences to a wider audience of students developing their abilities to problem solve in a variety of contexts and preparing students for future job opportunities within these STEM fields or beyond.

A journey is about appreciating where you started and understanding the lessons of the past. Past opportunities help construct the present landscape and help a person understand what influences decision-making. Chapter one introduced many of these past experiences and challenges; all have positively influenced my journey to this area of focus and research topic. Traveling to my family's favorite national and state parks introduced the power of nature and showed me how influential experiences in nature can be. These adventures challenged me to share nature with others beginning with summer campers and transitioning to nature centers and adventure-based organizations.

Ultimately, my experiences in a middle school science classroom at a STEM magnet school pushed me to pursue a wider variety of teaching techniques to engage students and begin the process of helping them relate to their environment. However, there is a greater need in extending students’ understanding of the knowledge of science by engaging in STEM investigations to solve environmental problems as a means to increase environmental literacy. Increased environmental literacy ensures that today’s students understand the cycles of the Earth, question observations and policy decisions, and solve the environmental issues surrounding them.

In the upcoming chapter, a review of literature will provide the important background information about STEM education, environmental literacy and the implications of these educational endeavors. It is essential to examine the history of STEM education in school classrooms to understand how and why this teaching pedagogy positively influences the education of students. Environmental literacy is another important component of this area of focus. There is a rich body of research that helps shape not only the development of environmental literacy, but also the significance of generations becoming environmentally literate. Many studies illustrate the positiveness of STEM and environmental literacy separately; however, there is little research that links these two topics together measuring the effectiveness of using STEM to solve environmental problems as a means to increase environmental literacy.

CHAPTER TWO

REVIEW OF LITERATURE

Introduction

With booming populations, dwindling natural resources and the increasing needs for greener infrastructure, many social and environmental challenges face individuals living in today's world. Do middle school students have the skills, perspectives, and experiences to prevent these problems from becoming issues while confronting these challenges directly? While in school, students are captive audiences and in position to develop problem solving skills in safe, cognitively and developmentally appropriate ways; when students gain skills to fully understand the challenges of today and the future, they are able to change the world around them. Both inquiry-based and project-based learning approaches ask students to evaluate environmental problems while probing for solutions while weighing out these solutions and examining the greater impacts these solutions might have.

Chapter two outlines the literature relating to the research question: *How does integrating STEM-themed environmental investigations in the middle school classroom impact environmental literacy?* The first section shares research regarding the target audience of this area of focus: middle school students. There are many factors that impact a middle school student's ability to grow and learn; these considerations must be taken into account in order to develop learning structures, such as inquiry-based and the project-based instruction that foster growth. In the next section, STEM (science, technology, engineering and mathematics) education will be considered. STEM education has a rich history of equipping innovative individuals with inquiry and problem-solving skills necessary in any career path that will be explored. The topic of green STEM is highlighted as a means of using inquiry-based learning to explore environmental problems that are localized for middle school students. In the last section of this literature review, the topic of environmental literacy is introduced as a goal for environmental education. The dynamic history of environmental literacy includes both global and local roots with a goal of creating citizens that can understand environmental issues and take action to remediate issues and prevent future issues from taking hold. Explorations of the connections among STEM, inquiry-based learning and environmental literacy concludes this section.

Middle School Students

Puberty plays an important role in the minds and bodies of middle school students. They are challenged by their developing bodies, hormone surges and the social interactions of their dynamic worlds (Armstrong, 2006). Because of these changes and challenges, there are unique ways of reaching these adolescent learners. This section provides an overview of the exceptional needs of middle school learners and how specific learning models such as inquiry-based learning and project based learning meet these challenges. In addition, the last section will refute why others believe inquiry and project-based learning can be ineffective in some research studies (Kirschner, Sweller & Clark, 2006).

Changing minds and bodies. The adolescent developmental period is a time marked with vast changes from cognitive brain development to social and relational changes to physical growth spurts and maturation (Ernst, Pine & Hardin, 2006). Puberty changes many things for middle school students and impacts learners' abilities to think, process and learn; young adolescents are much different than elementary or high school learners and require dynamic teaching methods and learning opportunities (Armstrong, 2006).

Crawford (2007) argued that puberty impacts students differently, there is much diversity (developmentally and physically) in middle school learners and that this age group is one of the most varied age groups in the education world presenting unique challenges to middle school educators (p. 2). At ages 11 to 12 years old, middle schoolers enter the formal operations developmental stage where they begin to understand how abstract relationships form, think inductively, analyze data, and explore how they think and process problems (Manning & Bucher, 2005). One of the cognitive implications and developments of adolescent learners is in the way they begin thinking about how they think, pose solutions to problems and develop abilities to evaluate and make decisions (Armstrong, 2006; Manning & Bucher, 2005). These new skills and developmental abilities allow adolescent learners to foster completion of new complex tasks such as problem-solving and investigative initiatives.

With these new cognitive developments comes additional challenges as learners engage in problem-solving. The complex nature of these problems require unique motivational methods in order to sustain engagement in solving these difficult problems (Anderman & Sinatra, 2012). Armstrong (2006) used an analogy between a middle schooler's brain development and a car's gas pedal saying that, "young teen's brains have their accelerators pressed all the way to the floor, while their brakes have yet to be installed" (para. 8). Further research initiatives are needed to explore the complex relationships between the brain, behavior development, self-regulation and motivation (Ernst et al., 2006). Researchers (Anderson & Sinatra, 2012; Ernst et al., 2006) inferred that these complex relationships impact academic achievement.

Unique learning needs of middle school students. Although middle school students are not in positions to commit to certain career fields, they are in the process of formulating their self-awareness and building specific skill sets that benefit them in any career path they might take (George, Stevenson, Thomason & Beane, 1992). Educators need to understand the challenges that adolescents face in the areas of puberty, brain development as well as the challenges of the 21st century in order to help these learners progress in both the educational and social world (Anderman & Sinatra, 2012). Armstrong (2006) wrote:

> The biggest need for young adolescents in education is not getting higher test scores, but rather learning how to direct those surging emotional impulses into productive channels, learning how to transmute the drive for mate-seeking into positive social relationships, and learning how to mobilize their newly developed metacognitive abilities in the service of reflecting on and modulating the transformations that are taking place in their bodies and minds. (para. 9)

Teachers need to intentionally plan active learning activities that promote growth in these new developmental areas. Lecture and textbook learning do not facilitate the same learning outcomes that active learning does (Armstrong, 2006). Current brain research studies reiterate the necessity of students experiencing multiple modes of learning new information and utilizing this new information (Arzy-Mitchell, 2013). According to the National Science Teachers Association Board of Directors (2003), curriculum for middle school students should foster creativity utilizing “hands-on, minds-on inquiry-based” instruction and this developmental period should provide middle school students with opportunities to expand their enthusiasm for science content and STEM-based careers (para. 4). Multiple STEM careers call for employees who not only have a passion for the specific content area, but also a skill base in logical thinking and problem-solving (Knezek, Christensen, Tyler-Wood & Periathiruvadi, 2013); these two areas represent growth opportunities for adolescent learners.

Understanding the unique brain-development changes that take place during middle school years directly influences the learning needs of these students and the instructional strategies implemented by educators (Arzy-Mitchell, 2013). Middle school is an important time in building students' knowledge and skill sets to actively engage in the difficult problem-solving required by the issues facing this generation (NSTA Board of Directors, 2003). Not without their own challenges, authentic problem-solving and investigations require scaffolding; this is an important support system that promotes middle school learners employing their critical thinking skills during these challenges (Anderman & Sinatra, 2012).

Inquiry-based Learning Theory

The National Research Council (2012) defined scientific inquiry as "the activities of students in which they develop knowledge and understanding of scientific ideas, as well as an understanding of how scientists study the natural world" (p. 23). There are four parts to inquiry-based learning: a driving question that has a basis in the real world of the learners, active investigations to explore the content of the driving question, true collaboration amongst all participants of these investigations and authentic use of technology to further explore the driving question (Krajcik et al., 1998). In science, students utilizing inquiry-based learning techniques are provided opportunities to develop plans to explore solutions to problems and questions while self-reflecting on their own process used to investigate problems (Chen & Howard, 2010).

In addition, inquiry-based investigations provide learners opportunities to repute findings (Krajcik et al., 1998) which is something that middle schoolers need opportunities to practice in safe environments as they develop abilities to respectfully disagree and use evidence to support claims. For the purpose of this research project, investigations are learning activities where students actively investigation a topic or inquiry question. The combination of learning new content and using inquiry skills to do so is important as students ask critical questions gleaned from actively participating in investigations (Krajcik et al., 1998). Students are allowed to explore the questions that surround them while creating connections between this new knowledge and the questions that initially fostered the new learnings (Chen & Howard, 2010). Furthermore, inquiry-based learning focuses on building on prior knowledge or a common experience (Witt & Ulmer, 2010, p. 272) which creates a natural safety net for developing learners.

With inquiry-based learning, the teacher takes a side seat acting much more like a facilitator versus an instructor (Savery, 2015, p. 16); this shift in power places increased responsibility on students to direct their own learning and make decisions about the methodology used in their explorations. A key characteristic about the adolescent developmental period is that middle school learners struggle to find their niche and inquiry-based instruction forces students to rise to the occasion because the students are the center of the learning experience (Witt & Ulmer, 2010, p. 272).

Project-based learning approach. Inquiry-based learning is a large umbrella under which project-based learning approach is based (Al-Balushi & Al-Aamri, 2014; Savery, 2015); two significant additions to this learning approach are the real world problems that serve as the origin of these learning activities and the products produced as a summary of learning (Al-Balushi & Al-Aamri, 2014). Verma et al. (2011) stated that the project-based learning approach requires active participation (p. 26); furthermore, Al-Balushi and Al-Aamri (2014) said that analyzing real world problems to identify solutions are important components of active learning in relation to environmental problems (Al-Balushi & Al-Aamri, 2014, p. 214).

The project-based learning approach asks students to investigate a real problem in order to learn science content and capitalizes on adolescent learners' desire to positively contribute to their world (Harmer & Cates, 2007). Middle school learners begin to evolve in their capabilities of moral and ethical decision-making while solving real-world problems (Manning & Bucher, 2006). As these new abilities develop, it is important to place students in positions where they can practice this, such as acting as problem-solvers while determining solutions to real-world issues (Arzy-Mitchell, 2013). During these experiences, middle school learners begin to implement all the steps of basic problem-solving, such as analyzing evidence, examining all perspectives and then deciding which solution might be the best (Manning & Bucher, 2006).

In project-based learning, learners need to employ metacognitive skills and practice their self-regulation strategies (Anderman & Sinatra, 2012) which are also skills that are newly developing in middle school students. Furthermore, reflection is another key topic in this learning style, meaning students need to think about how they are solving the problem in order to solve the problem (Arzy-Mitchell, 2013; Kolodner et al., 2003, p. 507) and these abilities are transferable to other areas of their changing lives. Finally, Utarasakul (2008) concluded that students not only grow in improving content knowledge understanding, but also in the project-based learning approach, which equips students to investigate more of the environmental problems facing our society.

Challenges of Inquiry and Project-based Learning Activities

With the multiple researched benefits of inquiry and project-based learning, researchers have identified some constraints in these learning initiatives. Kirschner et al. (2006) identified both of these strategies as minimally guided, meaning learners are building their own knowledge during problem-based learning and inquiry learning. This minimal guidance places significant burdens on working memory as they process intensive amounts of information (Kirschner et al., 2006); with a heavier load on students' working memory, they can feel overwhelmed with decision-making and processing.

Wolf and Fraser (2008) identified time as a significant concern in regards to implementing inquiry-based learning. They compared the effects of small-scale inquiry investigations (one to two days in length) to the effects of no inquiry-based instruction at all. They found that there was positive growth in the areas of class cohesiveness; however, little statistically significant growth in the area of achievement was noted. Because of the multiple day time requirements of these intensive learning initiatives, most inquiry-based learning begins with teachers providing direct instruction; instead, authentic inquiry originates from a teacher posing a problem and allowing students to go in directions of their own choosing and passions (Doppelt et al., 2008). Kirschner et al. (2006) argued that due to time and working memory load, these learning strategies are nearly impossible for teachers to successfully implement.

Researchers noted additional concerns regarding the implementation of inquiry or project-based learning. These challenges include students' ability levels, skill levels, the authenticity of learning plans, amount of teacher support and opportunities for students' deep intellectual growth. For low-achieving students, the combination of intensive science knowledge and the needed collaboration skills, might be too great for the positive growth to outweigh the concerns and negatives of these learning styles (Doppelt et al., 2008). In examining studies for middle school students using inquiry as a basis for investigating, they had increased challenges in collecting and analyzing data in systematic ways, and utilizing this data to develop conclusions (Krajcik et al., 1998). These are key parts of scientists' investigations and there are significant differences between the methods utilized by an expert in a field with a great amount of experience and the methods employed by students who are brand new to the science content or problems (Kirschner et al., 2006; Savery, 2015; Verma, 2011). Observations from practicing teachers utilizing these teaching initiatives illustrated that effective learning depended heavily on teacher scaffolding when students could not move past problems that arose within their work; examples included directly teaching content knowledge, modeling, demonstrating and showing students how to collaborate (Aulls, 2002). There are benefits of teacher-moderated small group instruction and hands-on learning activities; however, these strategies promote learning, but do not provide growth in the area of deep intellectual development (Schuck, DeHaan & McCray, 2003).

Researchers also noted evidence of unintended negative consequences among students learning in unguided ways in the areas of building misconceptions, incomplete knowledge or disorganized knowledge (Kirschner et al., 2006). Hmelo-Silver, Duncan and Chinn (2007) noted that the traditional ways of measuring student growth, like multiple choice test questions or worksheets, do not necessarily illustrate the benefits of problem-based learning and inquiry-based learning because measuring quantitative growth in scientific reasoning and effective problem-solving is a complicated matter.

Despite the noted challenges of inquiry-based learning and the project-based learning approach, some studies have highlighted growing benefits in utilizing these initiatives. Knezek et al. (2013) observed that carefully planned inquiry was effective with measured increases in students' creative tendencies and content knowledge. Wolf and Fraser (2008) noted that after employing inquiry-based learning strategies, students' cohesiveness increased further community building amongst participants. Geir et al. (2008) measured increased standardized test scores after increased student participation in inquiry-based learning activities. To combat some researcher's concerns regarding students lacking the support and the abilities to perform these higher cognitive functions utilized in inquiry-based learning or the project-based learning approach, Krajcik et al. (1998) recognized the importance of teacher scaffolding in these academic pursuits and Chen and Howard (2010) discovered that scaffolded teacher input positively benefited student learning.

Middle school students are searching for their niche in their worlds (in and out of school) and developing abilities to problem solve and investigate. Inquiry and project-based learning approaches place students in charge of their learning direction requiring students to inquire about learning topics, and investigate to learn both connections and knowledge. These skills employ higher order thinking and add new depths to active learning. In the study, all activities utilize either inquiry-based learning or project-based learning, and most often both learning approaches are activated for students to actively seek solutions to local environmental problems.

STEM Education

The STEM education movement began as politicians and industry leaders recognized that the US workforce in STEM careers (broadly defined as scientists, engineers and technology-based careers) was dwindling (Kuenzi, 2008); financial support poured in aiding the implementation of STEM-based curriculum (Breiner, Harkness, Johnson & Koehler, 2012). STEM represents learning initiatives in the areas of science, technology, engineering and mathematics. This section focuses on the history and the renewed future of STEM education and STEM literacy (National Research Council, 2011). The next sections explore the characteristics of a STEM education and integrated STEM, a new application in the STEM arena where multiple content areas collectively plan and facilitate learning experiences (Sanders, 2009) and recent national learning standards that highlight the importance of STEM fields and the environment (National Research Council, 2012). Finally, the connections between inquiry-based learning, project-based learning (Verma, 2011) and green STEM are explored in the last section of this topic.

History of STEM education. The American Association of the Advancement of Science (AAAS) identified that the concepts of science, math and technology cannot be separated from each other in order to teach them thoughtfully; instead, these content areas should be meshed together providing authentic learning experiences for all students (1995). STEM stands for learning initiatives in the content areas of science, technology, engineering and mathematics. STEM education originated early in the 1990's within the National Science Foundation and grew because of governmental concerns and increased policies regarding STEM education (Breiner et al., 2012, p. 4). The dynamics of global economies and environmental challenges of global populations requires more students to graduate with experience in the STEM content areas and technological skills to regain the US's competitiveness amongst other strengthening global powers (Breiner et al., 2012, p. 3). Sanders (2009) said "China and India were on course to bypass America in the global economy by outSTEMing us--funding began to flow towards all things STEM, and STEMmania set in" (p. 20). International marketplaces and economies were gaining in ambition where contracts and leverage were awarded based on an innovation race to the top (Holdren, Marrett & Suresh, 2013, p. 1). Some schools added "green technology" units at the request of local industry leaders as they searched for future employees that would have the necessary skills to take positions within their companies (Zalaznick, 2015). Stevenson (2014) noted that there were discrepancies between the reports of needing to bolster the STEM workforce in the United States and reports that there were not enough job opportunities for the STEM graduates already out of college.

STEM education using an integrative approach. As stated earlier, STEM is an acronym that stands for science, technology, engineering, and mathematics; however, the learning experiences create connections that extend beyond the content areas contained within the acronym (Mueller, 2014, p. 2). The National Research Council (2011) identified three goals of STEM education; they include increasing the enrollments of students in STEM-based careers enriching the number of female and minority students, extending the workforce in STEM areas, and building the STEM literacy of all individuals despite whether the students opt to pursue a STEM career or not (pp. 4-5). Bybee (2013) said "education should contribute to a STEM-literate society, a general workforce with 21st-century competencies, and an advanced research and development workforce focused on innovation" (p. x). The National Research Council (2011) defined STEM literacy as "the knowledge and understanding of scientific and mathematical concepts and processes required for personal decision making, participation in civic and cultural affairs and economic productivity for all students" (National Research Council, 2011, p. 5).

A newer addition to the STEM movement is integrative STEM where students focus on real-world problems, solve those problems while integrating these themes across multiple content areas (Breiner et al., 2012, p. 5; Sanders, 2009, p. 21). When using the integrative approach, school subjects are connected together instead of instructed in isolation (Barcelona, 2014). The integrative STEM approach also supports the middle school model where teachers are encouraged to plan learning opportunities that are spread between each of the content areas (Sanders, 2009, p. 21). STEM is more than just science and engineering content areas; STEM skills encourage creative thinking and innovation (Mueller, 2014, p. 2). Furthermore, integrated STEM learning is not just for budding engineers or up and coming scientists; the skills learned and practiced lay the foundation for all productive citizens in any future career path (Barcelona, 2014). The integrative STEM approach is hypothesized to increase students' sustained interest in STEM careers and content areas (Sanders, 2009, p. 22). In a preliminary meta-analysis study, Becker and Park (2011) found that an integrative approach positively correlated to greater academic scores in STEM subjects. They examined 28 studies that focused on different integration levels of STEM and predicted that an integrative approach used in teaching STEM topics improves STEM literacy of learners.

There are many characteristics that describe a STEM education and added benefits. “STEM activities provide a context and framework for organizing abstract understandings of science and math and encourage students to actively construct contextualized knowledge of learning areas, thereby promoting recall and learning transfer” (Sanders, 2009, p. 23). The STEM learning approach replaces traditional teacher-centered learning with inquiry and project-based approaches (Breiner et al., 2012) which increases engagement within middle school learners (Armstrong, 2006). STEM learning initiatives nourish students’ quest for innovation and foster the problem-solving skills needed to face the challenges of environmental changes (Soper, Fano & Hammonds, 2015, p. 14). In STEM-based investigations, there are plenty of opportunities for students to practice authentic real world learning where science inquiry and investigations are combined with design to determine solutions to the issues facing society (Sanders, 2009, p. 21).

Technology is an important part of STEM learning and enables teachers to plan STEM investigations that compliment the different learning styles and multiple intelligences of students (Chen & Howard, 2010). Any inventive technology should add to the learning experience instead of detracting from the quality experiences that STEM investigations initially offer (Zalaznick, 2015). Common technologies utilized during STEM investigations include data collection probe-ware, computer-assisted graphing programs, wind turbine design kits, and research databases. The technology utilized during STEM investigations enables students to visualize data, analyze data and take part in meaningful reflection regarding their solutions to problems; these are complex skills that students must practice before enrolling in more advanced levels of science coursework (Chen & Howard, 2010, p. 134). Assessing STEM activities requires multiple approaches such as formative and summative assessments tied to clear curricular goals (Honey, Pearson & Schweingruber, 2014) which benefits student learning as data is collected from multiple checkpoints and the teacher revises learning plans or scaffolding based on learners' needs. Bybee (2013) recognized that when students participate in STEM investigations, they gain 21st century skills while developing their cognitive abilities in content areas; there are five essential 21st century skills that are fostered during STEM education activities including: adaptability, complex communications, nonroutine problem-solving, self management and systems thinking (p. 38). A quality STEM education produces future engaged citizens that are STEM literate, able to understand and analyze the complex issues they will face, capable of posing clarifying questions and able to apply their background knowledge to further process through the environmental issues of the future (Fisher & Frey, 2014).

The importance of STEM education. Many innovations that Americans use daily like the Internet, robots and smartphones would not have been possible without a workforce that is both skilled and creative in the STEM areas (Holdren et al., 2013, p. 1). When college students begin their studies, less than 40 percent of them decide to focus on a STEM field (Olson & Riordan, 2012). Researchers use a leaky pipeline analogy to describe a phenomena occurring in the United States' education system in relation to STEM education (Soper et al., 2015, p. 13). There are not enough students entering the STEM career path as the job market demands according to government reports; students that could enter the STEM workforce are "leaking" into other career paths. This analogy describes the reduced number of students entering STEM careers with specific recognition of the concerning numbers of females and historically underrepresented individuals that study to be STEM professionals (Honey et al., 2014). Higher percentages of underrepresented populations opt out of pursuing careers in STEM areas (Sanders, 2009, p. 22) due to having fewer experiences with STEM content areas throughout their K-12 educational experience. Stevenson (2014) noted that students interested in STEM careers should be supported by teachers and parents as they learn the skills necessary to continue their educational pathway; however, students that are not interested should not be pushed aside or negated because they do not have an interest in a STEM profession. All middle school students are searching for their niche in the world and the importance of supporting all learners while they explore future job pathways is essential to students' continued development (Armstrong, 2006).

Many of the future's best paying jobs will require competencies within the STEM areas and problem-solving skills that extend out of STEM career paths (Breiner et al., 2012, p. 4). Future STEM job opportunities will require applicants to not only fully understand the knowledge of the job, but also be capable in analyzing problems and solving them (Knezek et al., 2013). Many countries will face increasingly difficult challenges such as economic stability, energy efficiency, improving environmental quality, limited resource conflicts, natural disasters, disease control and an increased demand for innovation (Bybee, 2013, p. 34). To combat these concerns, Holdren et al. organized the Federal Science, Technology, Engineering and Mathematics (STEM) Education Strategic Plan (2013) outlining five overarching goals to further build the United States' STEM workforce including improving STEM education, increasing STEM engagement for US youth by increasing the students' positive exposures to STEM activities, expanding graduation rates for college students and historically underserved populations focusing on STEM education majors, and growing the number of STEM-trained educators and professionals (p. viii).

Parents and family units have a profound impact of students questing for academic courses required for STEM training (Dorie et al., 2014). Inspiring students to engage in rigorous STEM learning experiences must begin at much younger grade levels than high school and college (Tai, Qi Liu, Maltese & Fan, 2006, p. 1144). Students commonly opt out of rigorous classes in the areas of high school math and science thus potentially graduating with low abilities (Sanders, 2009, p. 22) this can limit their college and career choices. In ninth grade, students were more likely (51%) to enroll in a more rigorous math class if their parent had a master's level degree (National Science Board, 2014, p. 4) and with fewer students enrolling in these classes, researchers indicate that STEM college enrollments are negatively impacted (Tai et al., 2006). In addition, Christensen, Knezek and Tyler-Wood (2015) cited parents/family members as the number two influential factor in students' interest in STEM. Future decision-makers need to build science and technology skills in order to make informed choices like understanding medical advice, analyzing the nature of environmental issues and using technology (National Research Council, 2011, p. 5). STEM literacy for all is important as individuals make decisions on purchases at stores and evaluate problems while analyzing the outcomes to potential solutions (Holdren et al., 2013, p. 1). Furthermore, "STEM literacy should be coupled with encouraging a life-long love of learning through the wonders that constitute STEM" (Stevenson, 2014, p. 141). When students experience quality STEM learning opportunities, these learning activities foster much more than STEM learning.

STEM education in the middle school. STEM and the engineering design process are paramount focuses of the Next Generation Science Standards (NGSS) released in 2013 (Honey et al., 2014). The NGSS focus on utilizing scientific inquiry and the engineering design process as integral components of science education (Soper et al., 2015, p. 14). The NGSS originated as a response to the limited number of innovative and economic advancements in the United States compared to other countries, as well as to the technological and scientific thinking skills required by twenty-first century employers (NGSS Lead States, 2013). With a spotlight on authentic problem-solving that includes STEM content areas and skills, implementation of the NGSS will result in the development of greater understandings, improved knowledge and scientific reasoning for students (Honey et al., 2014). NGSS encourages students to build connections between all school content areas (Honey et al., 2014) which is also a focus of integrated STEM instruction (Sanders, 2009).

Using the leaky STEM pipeline analogy discussed earlier, Soper et al. (2015) recognized that students' disinterest in STEM areas occurs early on in education, not necessarily in college, but much younger in middle school or even high school (p. 13). George et al. (1992) noted that STEM-based learning opportunities are an essential component of primary-school instruction. To fulfill the need for more STEM workers and a STEM literate country, governments and educators need to ensure that children (middle school and younger) have positive experiences with STEM topics because research indicates that students who demonstrated an early interest in these STEM fields were more likely to complete a degree in those areas (Tai et al., 2006, p. 1144). Becker and Park (2011) observed that utilizing an integrative approach to STEM content yielded improved understanding of STEM topics, STEM literacy and that early exposure to STEM-based learning provides a stronger foundation for learning.

Green STEM learning and connections to inquiry-based learning and the project-based learning approach. The National Wildlife Federation's Eco-Schools USA program combined the STEM approach with an environment-focused approach coining the term, “Green STEM” (Soper et al., 2015, p. 13). Nations across the globe face challenges such as explosive population growth, limited resources and unprecedented global climate change; societies will need to prepare for these challenges by re-evaluating current systems, replacing them with greener (low carbon) systems (Soper et al., 2015, p. 12).

Green STEM connects young problem solvers to local issues that directly impact their communities (Arndt & Tweed, 2015). These projects focus on local issues such as conservation, improving qualities of life and sustainability that will directly impact students (Zalaznick, 2015). There are four focuses of environment-based education and Green STEM: interdisciplinary learning, project-based learning, student-centered investigation and constructivist approaches such as inquiry (Soper et al., 2015, p. 16). Even with these focus areas, there is not a pre-determined equation for Green STEM planning because the problems students solve are localized (Arndt & Tweed, 2015).

Arndt and Tweed (2015) emphasized some critical steps for educators interested in using a Green STEM teaching approach; these steps include identifying a local green challenge that the engineering design process can be used to solve and using a STEM context to centralize all driving questions, action steps and connections. All of these steps highlight the key characteristics of both inquiry-based learning and the project-based learning approach because

Green STEM initiatives focus on making observations in order to identify environmental problems followed by asking questions regarding student observations and notations; in the project-based learning approach, learners investigate the environmental problem they identified through the inquiry activities (Hoepfl, 2016).

Much concern regarding STEM education centers around countries, maintaining their innovative edge; however, STEM education goes much farther than this. STEM literacy is for everyone, even if students move towards a humanities degree rather than a STEM degree; the skills garnered through STEM literacy initiatives promote innovation, understanding complex healthcare choices, asking clarifying questions to gain a deeper understanding of problems or issues that impact the learner and problem-solving. If the focus of local, real world problems is maintained, students have much educational benefit to gain. Green STEM is a union between STEM literacy and environmental problem-solving. In this study, only local environmental problems are used as learning focuses; students are actively solving issues they see each day and that impact them directly.

Environmental Literacy

Environmental literacy is broken down into six components: environmental sensitivity, ecological knowledge, environmental attitudes, issue and action skills, willingness to act and actual commitment (McBeth & Volk, 2009). This continuum of skills and abilities (Roth, 1992) allows individuals (including middle school students) to develop the knowledge and problem-solving skills necessary in facing environmental issues and developing positive attitudes towards environmental issues (Murphy & Olson, 2008). This section discusses the history of environmental literacy and provides an outline of different environmental literacy components.

Secondly, this section describes the significance of environmental literacy in adults and youth, highlighting methods of measuring the environmental literacy in children and adolescents. Lastly, this section researches connections between environmental literacy, STEM education and middle school learners.

History of environmental literacy. Environmental literacy was first mentioned by Charles Roth in 1968 when he inquired, "How shall we know the environmentally literate citizen?" (as cited in McBride, Brewer, Berkowitz & Borrie, 2013, p. 3). Later, Roth (1992) identified that society understood the definition of environmental illiteracy far before citizens understood the characteristics of an environmentally literate citizen. As society began to recognize their negative influences on the Earth (from their advancements in the areas of chemical pesticides like DDT, water quality and technological development), they also recognized that "environmental illiteracy was no longer acceptable" (McBride et al., 2013, p. 4). Roth (1992) identified environmental literacy as a continuum ranging from nominal environmental literacy, where individuals can recognize terms and concepts yet only are casually concerned about environmental problems and issues. The continuum continues to functional environmental literacy, where skills are added, enabling individuals to act on and articulate positions regarding environmental issues and even communicate these ideas with others. Operational environmental literacy concludes the continuum where knowledge, experience, and understandings are assembled into action steps relating environmental issues with solutions (Roth, 1992).

The Tbilisi Conference Declaration (1978) outlined environmental education objectives that shaped the definition and outcomes of environmental literacy; they included awareness, sensitivity, attitudes, skills and participation (Hungerford & Volk, 1990, pp. 257-258). These objectives encouraged individuals to understand the environment, think critically about environmental issues and actively participate engaging with environmental issues worldwide. From October 14-26, 1977 in Tbilisi, Georgia (USSR), 265 worldwide delegates and 65 representatives gathered to participate in an intergovernmental conference on environmental education sponsored by the United Nations Educational Scientific and Cultural Organization (UNESCO) and the United Nations Environment Programme (UNEP). During this meeting, a definition of environmental education was developed. The Tbilisi Declaration provided points of connection for students to identify and pose resolutions to the environmental issues facing today's generation (McBeth & Volk, 2009, p. 56).

As the environmental education movement emerged in the 1970's, special focus on environmental issues and problems followed, and the main focus of environmental education was instilling environmental literacy in all people (McBride et al., 2013, p. 5). Historically, the goal of environmental literacy has been to increase individuals' abilities to make pro-environmental behavior choices; however, the journey to these environmentally-sound decisions is not linear and not solely based on gaining environmental knowledge as previously understood (Hungerford & Volk, 1990; Ramsey et al., 1981). Environmental literacy broadens the skills needed to increase these pro-environmental behavior choices to include action skills and sensitivity to environmental issues (Moseley, 2000, p. 24) which are key components partnered with building environmental knowledge.

Importance of environmental literacy. As populations continue to grow, having equitable access to clean water, air and space will become an even more significant global challenge; the consequences of these challenges will be felt in both the environmental and social world (Hollweg et al., 2011, p. 1). Having environmentally literate individuals is important because community members need the knowledge and action skills necessary to take on the environmental issues that directly impact their communities (Murphy & Olson, 2008, p. 2). Environmental literacy reflects the complex limitations surrounding communities such as growing personal beliefs, complex experiences, new social dynamics and environmental issues that arise, change and develop (Hollweg et al., 2011).

"Direct responses to global environmental problems can slow the tide of environmental degradation, but reversing the trend requires an environmentally literate citizenry" (Stevenson, Peterson, Bondell, Mertig & Moore, 2013, p. 1). Research indicates that an informed and knowledgeable community base positively impacts the behaviors and choices of individuals (Murphy & Olson, 2008, p. 2). Environmental literacy equips individuals to solve looming environmental challenges and problems (Stevenson et al., 2013, p. 1). As students broaden their environmental literacy, they are also acquiring and practicing 21st century skills that will be essential to many of the career pathways of the future (NEEF, 2015, p. 96).When the need for clean water, clean air, food and energy is dominated by environmental issues, environmental literacy can improve the outcomes of these conflicts so more sustainable solutions are posed (Hollweg et al., 2011, pp. 5-9). Landers, Naylon and Drewes (2002) wrote in Minnesota's *Environmental Literacy Scope and Sequence* regarding the need for environmental literacy benchmarks for Minnesota students,

> If we are environmentally literate about our own choices, we travel with eyes wide open into our futures. We are far better prepared for any unwelcome consequences that we

> endure because we valued the trade-off more, and we are better prepared to live within the physical and social boundaries we know are there. (p. 4)

Environmental literacy prepares students to identify environmental problems, work towards solutions and prevent challenges from building into problems or issues.

Characteristics and measurements of environmental literacy. "The ultimate aim of education is shaping human behavior" (Hungerford & Volk, 1990, p. 257). Roth (1992) defined environmental literacy as "the capacity to perceive and interpret the relative health of environmental systems and take appropriate action to maintain, restore, or improve the health of those systems" (p. 2). The North American Association for Environmental Education (NAAEE) (2000/2004) defined an environmentally literate person as 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" (para. 6). Environmental literacy combines taking issue with the concerns of the environment while being knowledgeable, skillful and motivated to discover solutions to environmental problems with a heightened focus on preventing the problems of the future (NAAEE, 2004).

There are multiple frameworks characterizing goals and objectives of environmental literacy; however, environmental problem-solving is a common theme between many of these frameworks (McBride et al., 2013, p.6). The National Science Teachers Association (NSTA) highlighted the importance of using environmental education to create environmentally literate students as a means to foster problem-solving for environmental issues (NSTA, 2003). In the *National Environmental Literacy Project* (2009), McBeth and Volk outlined six areas of environmental literacy, including environmental sensitivity, ecological knowledge, environmental attitudes, issues and action skills, willingness to act and actual commitment-behavior (p. 57). The NAAEE identified four components of environmental literacy including environmentally responsible behaviors, competencies in identifying and analyzing environmental issues, environmental knowledge, and dispositions towards the environment (Hollweg et al., 2011).

In Minnesota's *Environmental Literacy Scope and Sequence* (2002), researchers Landers et al. defined the knowledge needed for students to make informed decisions and the grade level benchmarks necessary to complete the scope of knowledge (2002). Landers et al. (2002) also recognized the breadth of knowledge required to become environmentally literate, realizing that the time period needed to master such content is long (p. 4). The document outlines benchmarks for environmental literacy at grade levels pre-kindergarten-grade 2, grades 3-5, 6-8 and 9-12 (adult). Table 1 below outlines the environmental literacy benchmarks for grades 6-8 in Minnesota and highlights the key and supporting concepts for middle school students.

Table 1.

Minnesota middle school environmental literacy benchmarks and concepts for grades 6-8 (modified from Landers et al., 2002, p. 20).

Environmental Literacy Benchmarks for Grades 6-8 (Minnesota)
Social and natural systems can include processes as well as things.
The output from a social or natural system can become the input to other parts of social and natural systems.
Social and natural systems are connected to each other and to other larger or smaller systems.
Key Concepts: interactions and relationships, subsystems, inputs and outputs, change over time, population, cycles, trophic level, predation, migration, habitat, biome, scale, politics, economic, religion, niche, communities, waste, technology, diversity, extinction, innovation, and invention.

To further develop students' relationships with the environment, integrating both the cognitive and affective domains are needed to improve pro-environmental behavior (Littledyke, 2008). Being environmentally literate involves developing a deeper appreciation and awareness for the environment which is impacted by a person's environmental knowledge (Al-Balushi & Al-Aamri, 2014, p. 213). The goals of environmental literacy extend beyond gaining knowledge on environmental issues and problems questing to improve the citizenship and active participation of learners (Hungerford & Volk, 1990, p. 258). One of the prized components of environmental education is the opportunity for students to take what is learned in the form of content knowledge and apply this knowledge to investigate environmental issues (Hollweg et al., 2001, pp. 2-5).

As the field of environmental literacy develops, measuring the advancement of learners' environmental literacy is an important, yet complicated process (Hollweg et al., 2011, pp. 5-12). Measuring the environmental literacy of students requires much more than a quiz on science or environmental knowledge; researchers need to gauge if learners possess problem-solving skills, if students maintain emotional sensitivity toward the environment and if these skill sets lend to increased pro-environmental behaviors (NEEF, 2015). The complexities of measuring environmental literacy is vast having too much detail to be assessed in one general way (Hollweg et al., 2011). One instrument used to create a baseline of the environmental literacy of middle school learners is the *Middle School Environmental Literacy Survey* (MSELS) which combines questions and content from a wide variety of other instruments measuring nine indicators of environmental literacy, including knowledge, verbal and actual commitment, behavior, sensitivity, environmental feelings, issue identification, issue analysis skills and action planning (McBeth & Volk, 2009, p. 58).

Table 2.

National middle school environmental literacy results from the MSELS (phase 1 and 2) including grade level component scores and composite scores (modified from McBeth et al., 2011, p. xii).

Environmental Literacy Component	*MSELS Section*	*National 6th Grade Mean*	*National 7th Grade Mean*	*National 8th Grade Mean*
Ecological Knowledge	Ecological Foundations	41.68	44.11	43.77
Environmental Affect	Environmental Sensitivity Environmental Feeling Verbal Commitment	42.11	41.14	40.86
Cognitive Skills	Issue Identification Issue Analysis Action Planning	24.94	26.50	28.27
Environmental Behavior	Actual Commitment	40.90	39.89	39.46
Environmental Literacy Composite Score (240 possible score)		149.64	151.65	152.35

Connections between middle school learners, STEM and environmental literacy. McBeth and Volk (2009) measured the environmental literacy of middle school learners using the MSELS finding that students scored highest in the environmental knowledge (40.34) category and lowest in cognitive skills (25.56) which includes action planning and scientific inquiry (McBride et al., 2013, p. 7). In addition, they found that their environmental attitudes were relatively positive, especially in terms of taking action towards environmental problems. In contrast, they found that students lacked the necessary problem-solving skills needed to remediate some of the environmental issues that surrounded them (p. 63).

In an international attempt to measure the environmental literacy of fifteen-year-olds across the globe, the Organization for Economic Cooperation and Development (OECD) and their Programme for International Student Assessment (PISA) examined science content knowledge exploring a wide range of topics regarding the environment (2006). Researchers investigated five subject areas (health, natural resources, environmental quality, hazards, and science/technology) in personal, social and global contexts (p. 1). They found that students indicated that schools were the number one place where they learned about environmental topics and science. In addition, students from the United States scored lower on the PISA than other developed countries, including Finland, Japan and Canada in the areas of environmental issues and attitudes. This emphasizes the need for improving the United States' environmental literacy focus. Globally speaking, fifteen-year-olds felt a compelling interest in the environment and demonstrated a basic knowledge of science in answering environmental questions (Organization for Economic Co-Operation and Development & PISA, 2006, p. 11); however, becoming environmentally literate and sustaining positive environmental behaviors requires more than just science or environmental content knowledge (McBeth & Volk, 2009).

"Given that formal education is the pipeline that young people pass through on their way to becoming adult citizens, understanding this sector and how it can help create a more environmentally literate society is critical" (NEEF, 2015, p. 48). Middle school students are developing the abilities to cognitively process the issues facing their generation with a mindset of creating solutions (Stevenson et al., 2013, p. 2). Every person (including middle school students) needs to experience the power of learning about the environment and being part of problem-solving local issues that surround them (NEEF, 2015).

NEEF (2015) reported that STEM which combines interdisciplinary learning, inquiry-based learning and authentic problem-solving can positively influence environmental literacy (p. 96). During activities used to build environmental literacy, such as STEM investigations, students experience small scale problem-solving that can build the skills necessary to evaluate large scale environmental problems (Hollweg et al., 2011, pp. 2-5). Utarasakul (2008) found that using project-based learning which is utilized in some STEM classroom investigations both positively influenced the environmental knowledge base of learners and increased their awareness of environmental issues positioning learners to examine solutions for these issues. Al-Balushi and Al-Aamri (2014) found that environmental projects positively impacted environmental knowledge, which is one of the components of environmental literacy and non-traditional teaching approaches and initiatives that foster creativity should be utilized to increase engagement in environmental literacy goals.

In this study, a baseline environmental literacy of middle school students will be established. Then STEM-based learning activities that use both inquiry and project-based learning approaches will be used to measure the fluctuations in environmental literacy of middle school students. Much research has been done regarding the ideas of environmental literacy, the impacts of different factors on environmental literacy, and the complexities of measuring environmental literacy. These things must be taken into account when designing a study to establish data that examines the patterns of learning initiatives that focus on problem-solving, investigations and project development, and the dynamics of environmental literacy.

Summary

In this literature review, four main topics were explored, including middle school students, inquiry-based learning, STEM education and environmental literacy. Understanding these topics is essential in order to explore the research question: *How does integrating STEM-themed environmental investigations in the middle school classroom impact environmental literacy?* Middle school students are in a dynamic developmental stage where their abstract learning abilities are flourishing which requires experience in authentic problem-solving and inquiry-based learning to further practice abstract and critical thinking. Examining local environmental problems through a STEM lens provides opportunities for middle school students to build an environmental knowledge base, analyze the nature of problems, critically think about environmental issues from a wide variety of contexts and attempt to pose solutions to the environmental issues. These abilities model the objectives of environmental literacy. As discussed, having an environmentally literate society is essential as environmental problems and issues like growing populations, dwindling natural resources and clean water and energy initiatives, confront communities; engaging middle school students in investigations around these themes requiring them to build their science and environmental knowledge while exploring STEM solutions to the issues both their generation and future generations face fosters their developing environmental literacy.

In the Chapter three, the methodology for exploring the research question is investigated. The reasoning for selecting a qualitative research approach and the setting of the study with participant descriptions is explored in the next chapter. Finally, the topic of data collection is scrutinized with a special focus on measuring middle school students' environmental literacy before and after STEM-based investigations involving local environmental issues.

CHAPTER 3

METHODS

Introduction

There are important connections between middle school learners, STEM education and environmental literacy. These connections foster a partnership between the learner and educator with a sharpened focus on creating problem-solvers that can focus on the environmental problems generations face. One of the cognitive implications and developments of adolescent learners is in the way they begin thinking about how they think, pose solutions to problems and develop abilities to evaluate and make decisions (Armstrong, 2006; Manning, 2005). These new skills and developmental abilities allow adolescent learners to foster completion of new complex tasks such as problem-solving and investigative initiatives.

STEM is an acronym that stands for science, technology, engineering, and mathematics; however, the learning experiences create connections that extend beyond the content areas contained within the acronym (Mueller, 2014, p. 2). Multiple STEM careers call for employees who not only have a passion for the specific content area, but also a skill base in logical thinking and problem-solving (Knezek, Christensen, Tyler-Wood & Periathiruvadi, 2013); these two areas represent growth opportunities for adolescent learners. STEM learning initiatives nourish students' quest for innovation and foster the problem-solving skills needed to face the challenges of environmental changes (Soper, Fano & Hammonds, 2015, p. 14). Green STEM connects young problem solvers to local issues that directly impact their communities (Arndt & Tweed, 2015). These projects focus on local issues such as conservation, improving qualities of life and sustainability that directly impacts students (Zalaznick, 2015). As the environmental education movement emerged in the 1970's, special focus on environmental issues and problems followed, and the main focus of environmental education was instilling environmental literacy in all people (McBride et al., 2013, p. 5). Having environmentally literate individuals is important because community members need the knowledge and action skills necessary to take on the environmental issues that directly impact their communities (Murphy & Olson, 2008, p. 2).

This chapter looks at the methodology used to examine the research question: *How does integrating STEM-themed environmental investigations in the middle school classroom impact environmental literacy?* The details of the research paradigm are examined, along with both the setting and the participants of the study. Furthermore, the study's methods, and the collection and analysis of the data are discussed.

Research Paradigm

This study utilized an explanatory sequential mixed methods model, incorporating both quantitative and qualitative data with a direct focus on using qualitative data to clarify the patterns and understandings that the quantitative data presented (Creswell, 2014, p. 19). The most significant component of the study was the Middle School Environmental Literacy Survey (MSELS), which quantitatively measured four components of a middle schooler's environmental literacy. Qualitative approaches were also used to triangulate the quantitative data gathered, and included student interviews with probing questions regarding STEM activities and environmental literacy, and teacher observations during the investigation activities in a teacher-based reflection notebook. Further details of the sequential outline of these data sets are outlined in the methods section later in this chapter.

Mixed-methods studies allow researchers to observe the connections between quantitative and qualitative data which builds a deeper understanding than possible if only using quantitative or qualitative data gathering (Mills, 2014, p. 7). There is more flexibility in utilizing qualitative data gathering while quantitative research allows for a strong research structure (Creswell, 2014, p. 21). The limitations of this type of study include having enough time to properly synthesize both data sets, and having enough knowledge to identify connections, disparities and implications between quantitative and qualitative data (Mills, 2014, p. 8). A mixed methods research plan generally provides a quantitative survey to all participants followed by using a qualitative interview to measure differing views identified by the survey; this provides further details to clarify patterns that emerged from the survey (Creswell, 2014, p. 19).

Setting

This study took place at a pre-engineering STEM-magnet middle school (grades 6-8) in a suburban area. The STEM-magnet school focuses on utilizing thematic units, technology, and project-based learning to promote 21st century thinking skills. The school is one of four middle schools in the entire school district; the school has a regular attendance population within the school district and a magnet student population from more urban areas. These magnet students apply to attend the school through a lottery system. Curriculum planning revolves around four themes: technology applications, scientific communications, nature of science and technology, and STEM in society. These themes are integrated into all curricular content areas. In addition, the school uses a project-based learning approach with two significant large-scale projects including Science Fair and History Day.

Teacher demographics include approximately 40 teachers fully employed with 53.3% of teachers having 3-10 years of experience, 6% having less than 3 years of experience and 40.7% having more than 10 years of experience. Of the 750 students enrolled, 85.7% are White-non Hispanic, 5.9% are Black, 2.7% are Hispanic, 3.6% are Asian/Pacific Islander, and 2.1% are American Indian/Alaskan Natives. Of the 750 enrolled students, approximately 200 students are enrolled through the magnet attendance lottery or were open enrolled from other middle schools within the district.

Statewide, student achievement is measured through the Minnesota Comprehensive Assessment (MCA). In 2016, 75.7% of the school's students met or exceeded the standards on the Reading MCA assessment and 80.9% of the school's students met or exceeded the standards on the Math MCA assessment. The state averages for the Reading MCA assessment was 59.9% of statewide students meeting or exceeding the standards and the state average for the Math MCA assessment was 59.5% of statewide students meeting or exceeding the standards. Both of these scores were used to assess the appropriateness of using the MSELS for this specific audience.

Participants

Middle school students in seventh grade are typically 12 or 13 years old. Some students are local children from within our district's attendance zone and others are part of our magnet student population coming from the northwest suburbs surrounding a large midwest metropolitan area. Attendance zone students and magnet students were integrated in classrooms. Table 3 outlined participants' demographic data. They participated in a life science curriculum that is aligned to the Minnesota State Science Standards (grade 7). The students were enrolled in the researcher's life science course. Previous to this class, students received instruction as 6th grade students in physical science and the engineering design process.

Table 3.

Student participants' demographic information

Total Participants in the Study	131
Percentage Female	43.8%
Percentage Male	56.2%
Percentage that receive Special Education Services	13%
Average Class Size	29.2
English Language Learners in the Study	1

All participants were assigned one section of the researcher's life science class. Students attended these classes from 8:50 AM to 2:55 PM throughout the day.

Human Subjects Research Review Process

Permission was received from the school administrator to conduct research within the classroom and all the requirements of Hamline's Human Subjects Committee were met. Informed consent letters were signed by parents and guardians of research participants granting permission to take the MSELS, participate in student interviews and use investigation-derived assessment data in this research study. Participants were assured that published results of the survey, interviews and assessments were kept anonymous and confidential. Furthermore, basic safety precautions were undertaken during the learning investigations; these safety precautions modeled the lab safety contracts students were required to read and sign assuring that they will exercise caution when participating in lab work, investigations and collaborative group work.

Methods

Students participated in four different STEM-themed investigations during a four week period beginning the second full week of school for the 2016-2017 school year. These activities utilized inquiry-based learning and project-based learning; there has been a strong correlation of the use of both project-based and inquiry-based learning approach in STEM education (Soper et al., 2015). A learning plan is included in Appendix A. The MSELS pretest was administered prior to the investigation 1 and again following the investigation 4. Student interviews were conducted after the investigations, and after the initial and final MSELS to gain further understanding regarding patterns observed in the pretest data set.

Investigation 1 (see Appendix C) began with a guided water inquiry where students reviewed their knowledge of microscopes as scientific investigative tools that are used to examine small things, and students reviewed the characteristics of life (food, water, air and shelter). Students then focused on answering the inquiry question “Why is water important?” They used both observations from pond water (using the microscope) and their own research. Minnesota 7th grade science standards 7.1.3.4.2, 7.2.1.1.1 and 7.4.4.1.2 were assessed using this investigation. The inquiry investigation was assessed using a teacher-generated rubric and entered into the teacher’s gradebook.

Investigation 2 (see Appendix D) asked students to inquire about a local environmental problem and propose a solution to solve it; the summative project was a PSA video (under 1 minute) or an informational poster. Students self-selected the environmental issue and the summative project type (PSA video or informational poster). The poster or PSA video was assessed using a teacher-generated rubric and entered into the teacher's gradebook. Minnesota 7th grade science standard 7.4.4.1.2 was assessed using this investigation.

Investigation 3 (see Appendix E) asked students to use the engineering design process to solve the local environmental issue of improving the city's wind turbine to generate more power; the summative assessment included the solution, final test results and a student reflection. All items were assessed using a teacher-generated rubric. Minnesota 7th grade science standards 7.1.3.4.2 and 7.4.4.1.2 were assessed using this investigation.

Investigation 4 (see Appendix F) introduced students to using the scientific method to explore and design their own experiment around the topic of water quality. The guideline for the experiment was to answer the research question, "How do different materials impact the pH of water?" Students could select three different materials and test the pH of the water both before and after it passed through the material. Students planned their experimental design, received feedback on the design and then carried out the experiment. Minnesota 7th grade science standards 7.1.1.1.2, 7.1.1.2.2, 7.1.1.2.3, 7.1.3.4.2, and 7.4.4.1.2 were assessed using this investigation. The inquiry investigation was assessed using a teacher-generated rubric and entered into the teacher's gradebook.

Data Collection

This mixed methods study approach utilized both qualitative and quantitative data collection in an explanatory and sequential direction (Creswell, 2014). For this study, the direct method of gathering quantitative data was the MSELS and students took this digital survey before the learning investigations and after the learning investigations. The qualitative data collection tools were student observations during the learning investigations and 9 student interviews were conducted using 14 questions that sought clarification of quantitative data patterns.

MSELS. The MSELS (McBeth et al., 2008) was a 75-question survey with the first four questions asking about demographic information. Students took the MSELS prior to the learning investigations as a pre test and again following the learning activities as a post test. The study questions combined multiple choice responses and Likert-type responses and could be accomplished during a 50-minute class period. “The eight subtests of the MSELS are consistent with four major domains of environmental literacy: knowledge, affect, cognitive skills and behavior” (McBeth et al., 2011, p. 16). As seen in Table 4, these domains break into eight different measurable variables, including ecological knowledge, verbal commitment (intention to act), environmental sensitivity, environmental feeling, issue identification, issue analysis, action planning and actual commitment (behavior) (McBeth et al., 2011, p. 18). The consistency of the MSELS was measured using Cronbach’s Alpha Coefficient.

> Reliability estimates using Cronbach’s Alpha Coefficient were obtained from the field test of the MSELS and Alpha coefficients ranged from .389 to .869 for the different parts of the instrument. Additional reliability analyses using the 6th and 8th grade data from the Phase One national baseline study yielded Alpha coefficients ranging from .717 to .847. (McBeth et al., 2011, p. 17)

Using a readability scale based on the average number of syllables per 100 words, the MSELS scored a 66.4, which indicates a reading ease associated with grades six and seventh (McBeth et al., 2011, p. 18). Special permission was required to use the MSELS (see

Appendix B).

Table 4.

The correlation between environmental literacy components, MSELS sections and question numbers (modified from McBeth et al., 2011, p. 18).

Environmental Literacy Components and Correlating MSELS Sections		
Environmental Literacy Component	*MSELS Section*	*MSELS Question Number*
Ecological Knowledge	Ecological Foundations	5-21
Environmental Affect	How You Think about the Environment	22-33
	You and Environmental Sensitivity	46-56
	How You Feel About the Environment	57-58
Cognitive Skills	Issue Identification	59-60, 67
	Issue Analysis	61-66
	Action Planning	68.1-68.2
Behavior	What You Do About the Environment	34-45

Student interviews. In order to triangulate the quantitative data from the MSELS, fifteen student interviews were conducted in order to clarify any patterns in the MSELS pretest data gathered prior to the second learning investigation. Nine students were conveniently selected from a pool of students that had study hall during the researcher's non-instructional preparation time. As part of an explanatory sequential mixed method approach, these interview questions were drafted using national MSELS baseline data from 2008 and 2011 to further clarify observations and patterns (see Appendix G). These student interviews provided a greater depth of detail in regards to what impacts environmental literacy for this age group and provided participants opportunities to expand on their viewpoints.

Teacher observations. Teacher observations were used to triangulate data and gauge student engagement in the investigations. Teacher observations were conducted while students completed the learning investigations; the teacher observed behaviors, engagement, and conversations from four student groups for each class hour over the four week period. Student engagement is a high predictor of depth of understanding in investigations (Armstrong, 2006; Breiner et al., 2012). A graphic organizer was created by the researcher to record observations from student work time, brainstorming time and solution testing time (see Appendix H). Teacher observations provided the researcher an opportunity to discover the impacts of the learning investigations on the cognitive skills needed to solve STEM-themed challenges.

With any action research study, gathering data is important; in a mixed method study approach both quantitative and qualitative data are used to fully understand the impacts of the study. Students took the MSELS to identify the environmental literacy prior to the four learning investigations and took the MSELS after the learning investigations. National MSELS data was used to draft student interview questions and teacher observations during the learning investigations were used to clarify patterns in the school MSELS data results.

Data Analysis Methods

The original MSELS version was transferred to an online survey that utilized a secure log-in that specific targeted students could access on the test day only (with permission from the survey authors). For multiple choice questions, students received 1 point for a correct answer and 0 points for an incorrect answer. For Likert-scale questions, an A answer received 5 points, a B answer received 4 points, a C answer received 3 points, a D answer received 2 points and an E answer received 1 point. Once the data was gathered, the median, mode, mean and standard deviation were calculated for the entire data set (all students).

Based on patterns identified in national MSELS baseline data, interview questions were drafted to construct further opportunities to clarify student answers, determine the reasoning behind identified patterns and clarify meanings of answers. After the four investigations, students took the MSELS posttest to measure any changes in environmental literacy. Once the data was gathered, the median, mode, mean and standard deviation were calculated for the entire data set (all students). Student interviews occurred to clarify any potential reasons for changes (or lack thereof) in environmental literacy.

Summary

In order to examine the link between STEM-based learning activities and the environmental literacy of middle school students, students experienced four investigations and the MSELS was used prior to the learning investigations and following the learning investigations. The goal of using different instructional strategies like inquiry and project-based learning approaches was to gather data in regards to the research question: *How does integrating STEM-themed environmental investigations in the middle school classroom impact environmental literacy?* The MSELS measures four domains of environmental literacy including, environmental knowledge, affect, cognitive skills and behavior; these four domains are further broken down into 8 sub-areas including ecological knowledge, verbal commitment, environmental sensitivity, environmental feeling, issue identification, issue analysis, action planning and actual commitment (McBeth et al., 2011).

This study utilized an explanatory sequential mixed methods approach that focuses heavily on quantitative data with qualitative data used to further examine patterns and relationships observed in the quantitative data sets. Qualitative data was gathered using teacher observations during learning investigations and student interviews (used as needed) following the pretest and posttest. The audience of this study includes approximately 150, 7th grade students ranging in age from 12 to 13 years old. The study site is a pre-engineering STEM magnet school outside of a large midwest metropolitan area. Students receive STEM-integrated curriculum, specifically focusing on four areas including technology applications, scientific communications, nature of science and technology, and STEM in society. The school's curriculum also utilizes project-based learning and technology integration.

Four learning investigates took place where students were asked to identify local environmental problems, prepare solutions, create those solutions and then test the solutions. Inquiry, brainstorming, collaborative groups and reflection were key components of each of the four learning investigations. For the first learning investigation, students selected their own environmental problem (with a localized focus) and selected their own method of communicating their solution either with a PSA video or an informational poster. With the second learning investigation, students were given a localized environmental engineering problem, asked to create a solution and were given time to create, build and test their solution.

In the chapter four, the results of this study are analyzed and patterns among data sets are examined. The data gathered from these seventh graders is compared to the national baseline data for the same age group and the statistical significance is discussed. Finally, the implications of the data, patterns and trends is examined.

CHAPTER FOUR

RESULTS

Introduction

As middle school learners navigate the complexities of their developing abilities to analyze their surroundings, ask questions, and investigate real world problems, educators need to facilitate learning opportunities that foster these new skills (Armstrong, 2006). STEM-based learning provides inquiry-based and project-based learning investigations where middle school students put these developing skills into action and reflect on their process of solving unique problems (Chen & Howard, 2010). Environmental literacy combines taking issue with the concerns of the environment while being knowledgeable, skillful and motivated to discover solutions to environmental problems with a heightened focus on preventing the problems of the future (NAAEE, 2000/2004). This research project was designed to explore the research question: *How does integrating STEM-themed environmental investigations in the middle school classroom impact environmental literacy?*

This mixed methods study included both quantitative and qualitative data collection methods, and took place at a suburban pre-engineering STEM-magnet middle school including grades 6-8. The study lasted four weeks from September 13, 2016 to October 6, 2016; students took the MSELS as a pretest at the beginning of this period followed by participating in four environmental STEM-themed learning investigations (see Appendices C-F). Lastly, the MSELS served as a posttest at the conclusion of the four week study period. Quantitative data included the Middle School Environmental Literacy Survey (MSELS[1]) which was given to students at the beginning of the study and at the end of the study period. During the study period, qualitative observations of student engagement, understanding and challenges were gathered during student investigation using classroom observations. Lastly, nine student interviews took place near the end of the four week study period. Each component of the data collection process is examined individually with specific results and discussion. Following these close examinations, a synthesis of the entire qualitative and quantitative data set is summarized.

Review of Data Collection Methods

There were three main methods utilized to gather both qualitative and quantitative data: pretest and posttest MSELS, student observations during learning investigations, and student interviews. The data from these components was triangulated to draw conclusions about the environmental literacy of middle school students and the influences of environmental, STEM-themed learning investigations on their environmental literacy. The MSELS pretest was given to 131 students; six students had not provided consent at the time of the pretest MSELS and did not participate at this time; however, they later submitted their signed informed consent form after the pretest MSELS.

After the pretest MSELS, students participated in four learning investigations (see Appendices C-F) that utilized inquiry-based learning and project-based learning strategies which strongly correlated to learning approaches demonstrated in growth-orientated STEM education (Soper et al., 2015). These learning investigations asked students to use microscopes to examine pond water reflecting on the importance of water to living things, selecting a local

[1] The Middle School Environmental Literacy Survey (MSELS) is not found in the appendix due to copyright requirements

environmental problem explaining the problem and posing solutions or preventions using an environmental public service announcement, solving a local problem involving the city's outdated wind turbine technology by designing new turbine blades and testing the effectiveness of these blades, and designing an experiment to investigate the impacts of water pollution materials on the pH of water. During these investigations, the researcher observed student engagement, fluidity of student conversations during problem-solving, the difficulties encountered during work, and how well students could explain what problems they were attempting to solve in detail. Student engagement was a narrowed focus during these observations because it is a high predictor of depth of understanding in investigations (Armstrong, 2006; Breiner et al., 2012). The researcher utilized a graphic organizer to rate each observation component and then record further observation details (see Appendix H).

On October 6, 2016, 128 students took the MSELS as a posttest. The final component of data collection involved nine student interviews; students were conveniently selected and interviews took place during those students' study halls which correlated to the researcher's non-instructional, prep time. Student interview questions were drafted from the MSELS baseline data from 2008 and 2009, and further clarified observations and patterns from the researcher's pretest and posttest MSELS results (see Appendix G). Student interviews concluded the data collection period of this research study.

Pretest Middle School Environmental Literacy Survey (MSELS) Results

The pretest MSELS was a 75-question online survey including four demographic questions. There were eight different measurable variables within the MSELS including ecological knowledge, verbal commitment (intention to act), environmental sensitivity, environmental feeling, issue identification, issue analysis, action planning and actual commitment (behavior) (McBeth et al., 2011, p. 18). These eight variables measure the four larger environmental literacy components ecological knowledge, environmental affect, cognitive skills (issue identification, analysis and action planning), and behavior. The pretest MSELS took 23.4 minutes on average to complete and 131 students completed the pretest MSELS during the students' science class hour in which the researcher was the instructor.

The scores were reported as raw scores for each of the eight variables; these scores were adjusted to represent scores for four major environmental literacy components including ecological knowledge, environmental affect, cognitive skills and behavior. The adjusted scores were added to provide the cumulative adjusted scores for the testing group. As visible in Table 5, the cumulative adjusted score for students in this study was 150.14 out of a possible 240. Within each of these environmental literacy components and cumulative scores, there are score ranges for low, moderate and high. For ecological knowledge and cognitive skills, the score ranges included, low=0-20, moderate=21-40, and high=41-60; for environmental affect and behavior, the score ranges included, low=12-27, moderate=28-44, and high=45-60 (McBeth et al., 2011, p. xii).

Table 5.

Pretest mean raw scores and adjusted scores for the four environmental literacy components from the MSELS.

Environmental Literacy Component	*Environmental Literacy Variable (from MSELS)*	*Mean Raw Score(s) Pretest*	*Adjusted Score for Each Component*	*Score Range for Each Component*
Ecological Knowledge	Ecological Foundations	12.05	42.63	High
Environmental Affect	How You Think About the Environment	44.21	41.36	Moderate
	You and Environmental Sensitivity	35.90		
	How You Feel About the Environment	5.82		
Cognitive Skills	Issue Identification	2.60	35.36	Moderate
	Issue Analysis	1.31		
	Action Planning	13.69		
Behavior	What You Do About the Environment	30.79	30.79	Moderate
Cumulative Adjusted Score			150.14	Moderate

Because the MSELS is a national baseline survey, the data from the pretest was compared to the national trends regarding environmental literacy and middle school learners (see Table 6). From the first phase of the MSELS, 6th and 8th grade data was measured, and with the second phase of the MSELS, 7th grade data was added; however, only from schools with exemplary environmental education programs established within their schools (McBeth et al., 2011). Despite the fact that the researcher's study site does not have an environmental education program at all, data from the national survey and this survey are comparable because the MSELS testing instrument was similar.

Table 6.

Comparisons between national MSELS data for grades 6, 7 (phase 2), 8 and study data (pretest). Adjusted scores are out of a possible 240.

Environmental Literacy Component	*Grade 6 National Data*	*Grade 7 National Data*	*Grade 7 Pretest Study Data*	*Grade 8 National Data*
Ecological Knowledge	39.67	44.11	42.63	41.01
Environmental Affect	40.73	41.14	41.36	38.06
Cognitive Skills	25.15	26.50	35.36	25.98
Behavior	38.44	39.89	30.79	35.14
Cumulative Adjusted Score	143.99	151.65	150.14	140.19

The pretest gathered important and key details regarding the students' environmental literacy. Because the state does not have any baseline data regarding the environmental literacy of children, especially middle school, the data highlights the strengths and challenges within the different components of environmental literacy for local students. For comparison purposes, the students in this study compare well to the national 7th grade group that received exemplary school-based environmental education curriculum and opportunities; students in this study scored higher on two out of the four environmental literacy components without receiving any environmental education opportunities within the school day, and scored lower in ecological knowledge and behavior than the national 7th grade group. This was both an unexpected and expected discovery because STEM curriculum which is the focus of the study school has correlations yet a different focus from environmental education curriculum. Green STEM which was coined by the National Wildlife Refuge in 2015 (Soper et al., 2015) connects learning to local environmental problems (Arndt & Tweed, 2015). Green STEM was the guiding focus of how the learning investigations were designed in this study.

Posttest Middle School Environmental Literacy (MSELS) Results

On October 6, 2016, 128 students took the MSELS as a posttest (see Table 7). On average, students took 20 minutes to complete the posttest compared to 23.4 minutes for the pretest. Students were given the posttest to understand what changes, if any, developed over the four week treatment period. Within each of these environmental literacy components and cumulative scores, there are score ranges for low, moderate and high. For ecological knowledge and cognitive skills, the score ranges included, low=0-20, moderate=21-40, and high=41-60; for environmental affect and behavior, the score ranges included, low=12-27, moderate=28-44, and high=45-60 (McBeth et al., 2011, p. xii).

Table 7.

Posttest mean raw scores and adjusted scores for the four environmental literacy components from the MSELS.

Environmental Literacy Component	*Environmental Literacy Variable (from MSELS)*	*Mean Raw Score(s)-Posttest*	*Adjusted Score for Each Component*	*Score Range for Each Component*
Ecological Knowledge	Ecological Foundations	12.4	43.8	High
Environmental Affect	How You Think About the Environment	42.7	41.1	Moderate
	You and Environmental Sensitivity	36.7		
	How Your Feel About the Environment	6.0		
Cognitive Skills	Issue Identification	2.6	35.9	Moderate
	Issue Analysis	1.6		
	Action Planning	13.3		
Behavior	What You Do About the Environment	29.0	29.0	Moderate
Cumulative Adjusted Score			149.8	Moderate

Because the MSELS is a national baseline survey, the data from the posttest was compared to the national trends regarding environmental literacy and middle school learners (see Table 8). From the first phase of the MSELS, 6th and 8th grade data was measured, and with the second phase of the MSELS, 7th grade data was added; however, only from schools with exemplary environmental education programs within their schools (McBeth et al., 2011). Despite the fact that the researcher's study site does not have an environmental education program at all, data from the national survey and this survey are comparable because the MSELS (the testing instrument) was similar.

Table 8.

Comparisons between national MSELS data for grades 6, 7 (phase 2), 8 and study data (posttest). Adjusted scores are out of a possible 240.

Environmental Literacy Component	*Grade 6 National Data*	*Grade 7 National Data*	*Grade 7 Posttest Study Data*	*Grade 8 National Data*
Ecological Knowledge	39.67	44.11	43.80	41.01
Environmental Affect	40.73	41.14	41.10	38.06
Cognitive Skills	25.15	26.50	35.90	25.98
Behavior	38.44	39.89	29.0	35.14
Cumulative Adjusted Score	143.99	151.65	149.8	140.19

Pretest and Posttest Comparison

There were minor shifts between the pretest and posttest scores as outlined in the Table 9 below.

Table 9.

Comparisons between pretest and posttest MSELS results per component and adjusted scores.

Environmental Literacy Component	*Environmental Literacy Variable (from MSELS)*	*Mean Raw Score(s)-Pretest*	*Mean Raw Score(s)-Posttest*	*Adjusted Score for Each Component (Pretest)*	*Adjusted Score for Each Component (Posttest)*
Ecological Knowledge	Ecological Foundations	12.05	12.4	42.63	43.8
Environmental Affect	How You Think About the Environment	44.21	42.7	41.36	41.1
	You and Environmental Sensitivity	35.90	36.7		
	How Your Feel About the Environment	5.82	6.0		
Cognitive Skills	Issue Identification	2.60	2.6	35.36	35.9
	Issue Analysis	1.31	1.6		
	Action Planning	13.69	13.3		
Behavior	What You Do About the Environment	30.79	29.0	30.79	29.0
Cumulative Adjusted Score				150.1	149.8

According to Table 9, there are a few areas of growth from pretest to posttest. These areas include Ecological Knowledge (+1.70) and Cognitive Skills (+0.54). In addition, there were areas of decline including Environmental Affect (-0.26) and Behavior (-1.79). Neither of these shifts are statistically significant; however, these changes cause reason for closer examination using evidence from student interviews and classroom observations. The environmental STEM-themed investigations focused primarily on building knowledge, issue identification and developing or posing solutions to environmental problems. With these highlighted foci, the gains within the Ecological Knowledge and Cognitive Skills (issue identification, issue analysis and action planning) seem most relevant. These investigations were not designed to improve students' feelings towards the environmental or increase pro-environmental behavior choices for students; instead, the learning investigations focused on using project-based and inquiry-based learning which is illustrated by the positive growth in components of Ecological Knowledge and Cognitive Skills. However, students scored similarly in pretest results. Employing these instructional strategies in the learning investigations maintained students' strengths that were previously identified using the MSELS pretest.

Nationally, both the pretest and posttest results compare to the national 7th grade MSELS results from schools that have fully incorporated exemplary environmental education within their school programming. According to Table 10, students within this study exposed to environmental STEM-themed investigations grew closer to the national 7th grade average within the Ecological Knowledge component (43.8 compared to 44.11). Students within this study neared the national 7th grade data for Ecological Affect, and outscored the national 7th grade data for cognitive skills (35.90 to 26.50). Finally, students had an almost 10 point negative difference in the Behavior component compared to the national 7th grade data. Students within the study outscored the 6th and 8th grade national data in three out of four categories including Ecological Knowledge, Environmental Affect and Cognitive Skills. Nationally, 6th and 8th grade students outperformed the 7th grade students in this study in the Behavior component.

Table 10.

Comparing all MSELS data from pretest and posttest at all grade levels including national grade 7 data which was measured from schools that have fully fused exemplary environmental education into their school.

Environmental Literacy Component	*Grade 6 National Data*	*Grade 7 National Data*	*Grade 7 Pretest Study Data*	*Grade 7 Posttest Study Data*	*Grade 8 National Data*
Ecological Knowledge	39.67	44.11	42.63	43.80	41.01
Environmental Affect	40.73	41.14	41.36	41.10	38.06
Cognitive Skills	25.15	26.50	35.36	35.90	25.98
Behavior	38.44	39.89	30.79	29.0	35.14
Cumulative Adjusted Score	143.99	151.65	150.14	149.8	140.19

Within this study, environmental STEM-themed investigations did not focus on promoting pro-environmental behavior changes; however, the investigations concentrated on building ecological knowledge about local environmental problems while students worked to pose solutions or preventions. Utilizing project-based and inquiry-based learning approaches which are common factors in the 6th grade STEM curriculum that students were exposed to in the previous year of learning at the study school, might have impacted the higher than expected scores in Cognitive Skills (issue identification, issue analysis and action planning). A significant part of the engineering process that the study school uses is researching and identifying the problems that initiate the solution students are charged with designing. Most importantly, the high scores in Cognitive Skills were maintained over the course of this study resulting in +0.54 growth when pretest and posttest scores are compared.

Classroom Observations and Interview Results

Classroom observations. The researcher used a graphic organizer (see Appendix H) to gather observations about student engagement, effort, challenges that occurred during the investigations and the level of detail students explain regarding the investigation and the environmental problem that was the focus of the learning investigation. For three investigations (environmental public service announcement, wind turbine engineering and water quality experiment design), one student group per teaching hour was observed and asked questions from the graphic organizer; this resulted in five observed groups per investigation and 15 observations total during the entire research period. In table 11, mean ratings were calculated for each of the observable items (level of student engagement, level of student effort, student communication, level of detail in explaining the environmental problem that instigated the investigation).

Table 11.

Mean ratings (out of 5) from teacher observations during student work time.

Observable Item in the Classroom	*Environmental PSA*	*Wind Turbine Engineering*	*Water Quality Environmental Design*	*Mean Rating for all Three Investigations*
Student Engagement	4.2	4.8	5.0	4.7
Student Effort	4.0	4.4	4.8	4.4
Student Communication	3.8	4.4	4.9	4.4
Level of Detail	4.8	4.6	4.7	4.7

In addition to the quantitative ratings from the graphic organizer, students were asked to explain the difficulties they experienced during the three investigations. For the environmental public service announcement investigation, four out of five groups noted that they experienced difficulty with the technology component of this investigation. Many students utilized a web-based video design program that does not allow collaboration on projects meaning that only one student within the group can build and assemble the video. The entire group supported the process; however, students were wanting to all work on the video at the same time sharing more of the work. One student group opted to create a poster for their environmental public service announcement, and they noted that their difficulty was in making the billboard look “nice and professional.” As illustrated in Table 11, the average rating for student communication was 3.8; the researcher observed that some student groups were challenged by having to agree on the many different components of the environmental public service announcement.

In regards to the wind turbine engineering investigation, student groups rated higher in all components during classroom observations except level of detail. Students were asked to explain the environmental problem that led to this investigation, and in conversations, students used less detail than in the previous environmental public service announcement investigation. To understand this further, the researcher gathered a random sample of student papers (see Appendix E), and inspected the third reflection question which asked students to explain this information; 20 out of 24 papers correctly identified the environmental problem. This environmental problem appeared much more straightforward than the previous investigation (environmental public service announcement) because students were given the environmental problem instead of self-selecting a local environmental problem. In addition, engineering wind turbines was part of the sixth grade science curriculum; therefore, many students had stronger experience in regards to brainstorming, designing and constructing new wind turbine blades. Conversely, some students remembered the frustrations and negative emotions connected to the previous year's experience. Compared to the previous year's project, the engineering problem presented differently in this study's investigation and students used new technology (a multimeter) to measure how much energy the wind turbines produced. One group stated that they were experiencing difficulty in agreeing on an engineering design, and when a problem came up, they could not agree on a solution to try. Three out of five groups explained that time was a significant constraint in this investigation.

In the final investigation, Water Quality Experimental Design, students engaged with the idea of self-selecting their own experimental components including hypothesis, variables (independent, dependent, and controlled), and parts of their procedures. The method of measuring the impact of the materials on the water's pH was using pH indicator strips which were a new technology to most students. This measurement method was supported by using a pH probe and a chromebook to compare students' data gathered by pH strip and pH probe. This technology component was appealing to students. Two out of five groups noted that they were not experiencing difficulties with this investigation; three out of five groups noted that communicating and agreeing on the different experimental components was especially challenging.

Student interviews. Interviews were conducted with four female students on October 10, 2016 and with five male students on October 13, 2016. Interviewees were 12 years old (77.7%) and 13 years old (22.2%). Students were conveniently sampled based on having their study halls during the researcher's prep time to limit disruptions from the students' learning day. Interviews were conducted in the teacher's classroom which is a familiar environment, and lasted no longer than 10 minutes. Students were provided the interview questions the day before; however, they were not required to write any answers out unless they did by their own choice. Four out of nine interview participants wrote out answers to the interview questions; these students were all female. Themes emerged from these student interviews as illustrated in Table 12.

Table 12.

Number of positive and negative responses per interview question with common themes. Nine students were interviewed. A positive rating was assigned to a student's response if the interview answer supported being an environmentally literate student.

Interview Question	Number of Responses		Responses of Note
	Positive	Negative	
How much time do you spend outside?	8	1	1 student responded that in the cold he or she only occasionally goes outside
What are some activities you like to do outside?	9	0	8/9 responses noted playing some sort of sport activity
What are some barriers that prevent you from going outside as much as you'd like?	0	9	Barriers: cold weather, rainy, homework, after school activities
Is the environment important? If so- why? If not- why not?	9	0	All answers connected the environment to our survival
Does our community have environmental problems? If yes, what are some examples? If no, why not?	1	8	Litter was mentioned by 4/4 female students and ⅕ male students as a problem. 1 student mentioned natural disasters as problems in our community. 1 student did not recognize problems in our community.
What skills should people have that fix or prevent environmental problems?	9	0	All students identified that humans have the power to fix these problems with certain skills, and specifically mentioned that the behavior of picking up litter would be helpful.
How do you think schools do providing a place to help you learn how to identify and solve environmental problems?	9	0	All students remarked that schools do a "good" or "great" job

How did the water investigations impact your understanding of the environment?	8	1	All students had positive experiences except for one student that believed he or she observed bacteria and nasty things with a low powered microscope.
How did the wind turbine design investigation impact your understanding of the environment?	5	4	2 students did not know, 1 student did not think this was a positive experience, 1 student related wind turbines to crop production.
How did the environmental problem PSA (public service announcement) investigation impact your understanding of the environment?	9	0	All students were able to identify local problems and were positive towards solutions or preventions.
Have you experienced any behavior changes since these investigations? If so, what are some examples? If not, why not?	7	2	Students that noted positive behavior changes explained specific behaviors they changed including using less water, picking up litter, and being more aware of our natural world.
In the last week, how many times do you think you've: 1. Recycled paper at school in the recycling bin (not trash)? 2. Recycled plastic bottles at home or school? 3. Turned off the water when brushing your teeth? 4. Ate leftover food instead of throwing leftover food away? 5. Picked up litter outside when you saw it?	1. Recycling Paper: 44.4% (Always), 44.4% (Mostly), 11.1% (Sometimes) 2. Recycling Plastic: 44.4% (Always), 33.3% (Mostly), 22.2% (not a lot) 3. Running Water While Brushing Teeth: 100% (never) 4. Eating Leftovers: 22.2% (Always), 55.5% (Mostly), 11.1% (Not usually), 11.1% (Not sure) 5. Picking Up Litter: 66.6% (Mostly), 33.3% (Sometimes); 44.4% (Mostly pick it up unless it is nasty)		
What are the most important things you have learned from the investigations?	8	1	2/9 students noted that seeing pond water critters was influential. 1/9 students noted that society has to work together to solve problems. 1/9 students did not know.

There are themes that emerged from a couple of responses to specific questions. For questions 2 and 3, there were strong correlations with students spending time outside to play or practice organized sports. Only 2 out of 9 students did not mention playing some sort of sport; instead, they described doing other activities outside including walking their dogs, taking walks, and riding their bikes. All students specified that schools do a “good” or “great” job at providing a place for students to learn how to identify and solve environmental problems. Two students specifically said that science classes and technology classes provide places for them to learn “hands-on” and places for them to “do stuff.” When students reflected on how the investigations that took place in class impacted their understanding of the environment, there were mixed responses. Almost all students (88.8%) reacted positively towards the water investigation where they utilized microscopes to view pond water, and they used great detail to describe the critters viewed and why these organisms are important; 1 student responded that he was viewing bacteria and other “nasty” things. However, with the magnification of our microscopes, seeing bacteria during this investigation was not possible.

Students acknowledged the effectiveness of the environmental public service announcement investigation; 100% of students said something positive about this investigation. Conversely, the wind turbine investigation received mixed feedback; 55.5% of students reacted positively, often connecting the ideas that wind turbines produce “clean energy,” and 44.4% of students reacted negatively, citing that they did not know or had a negative experience with the investigation itself (some students participated in a similar STEM investigation as sixth grade students). Finally, question 13 asked students to think about their own behaviors and tell how frequently they participate in some pro-environmental behavior choices in a typical week. These responses correlated strongly to the behavior questions on the MSELS. One question of note was 13a, students were asked how frequently they recycle paper here at school and 88.8% of students responded that they always or mostly recycle; furthermore, 22.2% of students kept the paper until a recycling bin was present if there was not one already there and 44.4% of students would put the paper in the trash if a recycling bin was not present. In addition, when asked how frequently students pick up litter that they find outside, 66.6% of students said they mostly pick it up and 33.3% of students said they sometimes pick it up; however, the reasons students explained for not picking up litter were interesting including, the litter being “nasty,” being afraid of traffic in the area of the litter and being in a rush.

Data, Observations and Interpretation

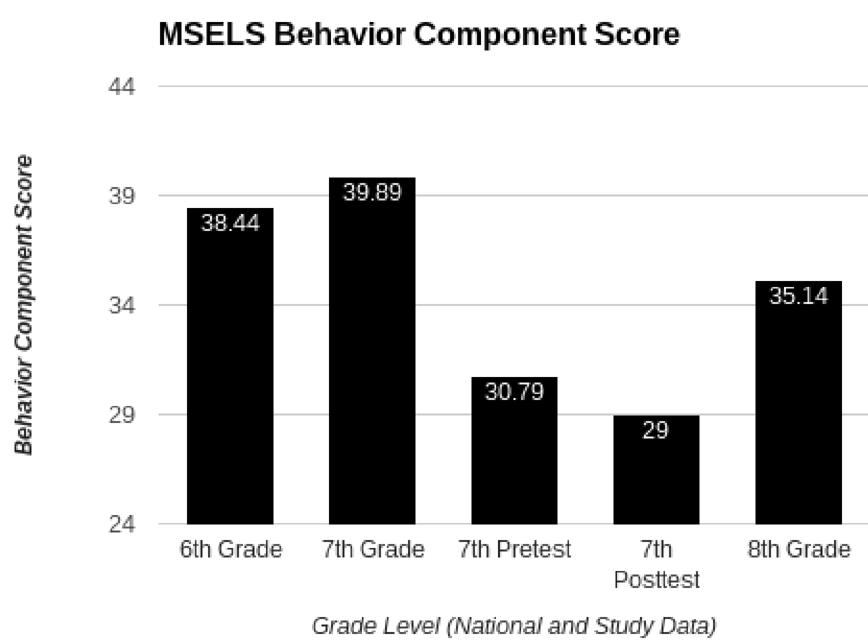
In using a mixed methods research approach, it is important for the researcher to synthesize patterns and observations for both qualitative and quantitative data gathered from the research project (Mills, 2014, p. 7). In this study, quantitative data was gathered from the MSELS survey (pretest and posttest), and scores from classroom observations; qualitative data was gathered from classroom observations and student interviews. There were a couple of correlations, explanations and patterns observed between these data sources.

When looking at MSELS scores and classroom observations, the students in this study scored high on the Cognitive Skills section which includes issue identification, issue analysis and action planning. Nationally, 7th graders scored 26.50 and students in this study scored 30.70 (pretest) and 29.0 (posttest). A significant part of the classroom observations within this study was to provide students an opportunity to describe the environmental problem in their own detailed words. Between all investigations, students scored 4.7/5 in this category. This skill of using detail to describe the problem that the investigation can be measured by and correlated to the MSELS survey section Cognitive Skills. Students in this study scored higher than the national 7th grade average for Issue Identification, lower than the national 7th grade average for Issue Analysis, and much higher for Action Planning compared to the national 7th grade average.

Student interviews provided great detail and insight into many components of this research question and project. On the MSELS, there was one component where students scored lower than the national average: Behavior. Figure 1 shows the difference for this MSELS component.

Figure 1.

MSELS behavior component score for national and study data.



This MSELS component measured students' actual commitment to pro-environmental behaviors; often this is contrasted to students' commitment or intention to act positively towards the environment. The discrepancy between students' commitment to act and their actual commitment is not anything new in the field of environmental literacy; however, the factors that construct how or why students act positively are complex and make creating learning opportunities to fill this void even more complex (Hungerford & Volk, 1990; Kollmuss & Agyeman, 2002). This holds especially true for middle school learners as they navigate the peer relations in their complicated social world. According to the MSELS, students in this study scored lower than any other participant category in both phases of this national survey including 6th graders, 7th graders and 8th graders. When the questions for this section were examined, responses depicted a mixture of positive and negative environmental behaviors. There are responses that are corroborated by student interview answers, and responses that need much deeper analysis to fully realize the instigating factors that interact with this behavior choice which is not present in this study.

On the MSELS, students were asked, "I have not written someone about a pollution problem," and 64% of students responded very true or mostly true. Although this question was not analyzed by classroom observations or interviews, students were asked to communicate regarding water pollution in two of the investigations that took place during this study; however, specifically writing to someone was not a study or investigation focus. This behavior expectation might be unrealistic for a 7th grade learner who relies primarily on social media and verbal communication on a typical day. Students were asked, "I turn off the water in the sink while I brush my teeth to conserve water," and 89% of students responded very true or mostly true;

these results are supported by student interviews because 100% of interviewed students said they do not run the water to brush their teeth. This seems like a very tangible behavior modification for students to make and from the interviews, a behavior that is instilled early in students by their family routines. Students were asked, “I have asked my family to recycle some of the things we use,” and 62% of students responded very true or mostly true; 38% responded that they were not sure, mostly false or very false. In student interviews, students were asked about their recycling habits (not if they ask their families to recycle), and 88.8% of interviewees said they recycle paper at school or home always or mostly, and 77.7% of students said they always or mostly recycle plastics at home or school. Students seem to have positive recycling habits; however, according to the MSELS, this might not extend to asking their families to recycle.

Students were asked, “I have asked others what I can do to help reduce pollution,” and 78% responded that they were not sure, mostly false or very false. During student interviews, 3 out of 9 students responsed that in developing their own environmental public service announcements, there were many resources available to learn more about environmental problems, they felt empowered to learn more about environmental problems, and they individually researched more about their environmental problem (outside of school). These interview responses illustrated that students took control of their own learning and did not necessarily rely on needing to ask others for information; instead, students sought this information in their own ways and on their own time. Finally, students were asked,” I do not separate things at home for recycling,” and 24% responded very true, mostly true or not sure; 79% responded mostly false or very false. Within the city in which this research study took place, families are not asked to sort recycling because the city offers single-sort recycling. This might mean that the 24% that responded that they do not sort recycling or are not sure should not be negatively interpreted because sorting is not essential for recycling within the city of focus. However, this might mean that the 24% do not recycle in the first place.

Student interviews demonstrated a much more outdoor-connected student audience with a much more positive outlook on why learning about the environment and STEM is more important than noted in the MSELS data. Many students noted that they feel connected to the outdoors by spending time outdoors, and make pro-environmental behavior choices; however, the MSELS survey did not necessarily reflect this. Students responded that they connect to the outdoors by playing or practicing organized sports. This presents in the literature as a common correlation. Playing sports does benefit the student by being active outside; however, unstructured play time outdoors is more beneficial in developing connections with the outdoors and the environment (White, 2008). MSELS data did reflect opportunities for growth in regards to students engaging in pro-environmental behaviors, and student interview questions did not necessarily cover the following topics: asking parents not to buy products made from animal fur, talking with parents about how to help with environmental problems, and reading stories that are mostly about the environment.

Summary

In this chapter, data collection strategies, MSELS results (pretest and posttest), classroom observations, student interviews and a synthesis of the qualitative and quantitative data were covered. Data gathered in this study focused on determining, *How does integrating STEM-themed environmental investigations in the middle school classroom impact* *environmental literacy?* Overall, the results demonstrated students scored moderately or high in all components of the MSELS which measures students' environmental literacy; however, students scored lower than typical for the Behavior component which measures the amounts of pro-environmental choices students make in their lives. Student interviews were useful in gaining insight and perspective on how students felt the STEM-themed learning investigations impacted their beliefs, understandings and behaviors regarding the environment and environmental literacy. Overall, students felt positively towards three out of four learning STEM-themed investigations, and felt positive towards how these learning investigations contributed to their understanding of the environment and their environmental literacy.

The focus of the learning investigations was to utilize project-based and inquiry-based strategies to learn about environmental topics, identify environmental problems, and generate solutions or preventions for these identified environmental problems. As identified in the MSELS results, students outscored every age group (6th, 7th and 8th grade national data) in the Cognitive Skills component which included issue identification, issue analysis and action planning. However, the students in this study outscored every age group prior to the investigations (pretest= 35.36 and posttest= 35.90); this illustrates that students began the study period with high Cognitive Skills abilities, and the high ratings might not have been a result of this research study's initiatives. Lastly, the results of this study indicate the competitiveness of schools that employ high quality environmental education and schools that employ STEM-based learning opportunities which cross-cut across all middle grade levels. Students scored comparatively in two out of four components including Ecological Knowledge and

Environmental Affect, and outscored environmental education schools in Cognitive Skills which is the focus of the STEM curriculum in general, not just the curriculum of this study.

In Chapter 5, the learnings and limitations from the research study will be explored in detail. The literature from Chapter 2 will be revisited with connections and questions being asked, and the future implications of these learnings will be examined. Finally, the researcher will examine any final ideas on how this study is important and useful to education as a whole.

CHAPTER FIVE

CONCLUSIONS

Introduction

This research project examined the question: *How does integrating STEM-themed environmental investigations in the middle school classroom impact environmental literacy?* The project followed a mixed methods research approach which utilizes both qualitative and quantitative data analysis. At the study's site, 131 middle school students participated in STEM-themed learning investigations that were based on local environmental problems and followed the instructional strategies used in project-based and inquiry-based learning. The main measure of students' environmental literacy was gathered by using a national Middle School Environmental Literacy Survey (MSELS) which was developed to measure and compare the environmental literacy of 6th, 7th and 8th grade students in the United States. The students took the online survey as a pretest and posttest; results from the MSELS were synthesized with classroom observations during the learning investigations, and nine student interviews that were conducted at the conclusion of the study.

In chapter 5, the learning and limitations from this research study are examined including both the expected outcomes and the unexpected outcomes. Connections from this study and the wealth of literature available on the topics of middle school students, environmental literacy and STEM education are investigated. Finally, the future implications of this study are considered with the perspective of how this research is useful to others.

Major Findings and Outcomes

From this research study, some of the major findings were expected outcomes based on information previously known about the study school and the literature, and there were unexpected outcomes that deviated from the literature. There is value in both of these types of outcomes. STEM-themed environmental investigations did not have a major impact on the growth of the whole measure of environmental literacy in middle school students; however, when the individual components of environmental literacy are examined, there are areas of slight growth, including ecological knowledge and cognitive skills (issue identification, issue analysis, and action planning) and there are areas of slight decline, including environmental affect, and behavior. Neither of these declines or growths are statistically significant.

Major Findings. This research project was designed to evaluate the effectiveness of STEM-based learning initiatives in improving environmental literacy, and to answer the following research question: *How does integrating STEM-themed environmental investigations in the middle school classroom impact environmental literacy?* There were multiple major findings from this research project that help understand the measures and influences of environmental literacy on the middle school audience. One overarching finding is the importance of understanding the components and measurements of environmental literacy, specifically for this adolescent age group. In the state in which this study took place, there are environmental literacy benchmarks that were created in 2002; however, there is not any statewide data on where students typically rate, or how teachers know if students are improving their environmental literacy. This study helps advocate for more authentic measurements for the environmental literacy benchmarks that already exist. For teachers to help facilitate growth of environmental literacy that will best prepare students to tackle the environmental problems of the future, a stronger basis of environmental literacy that is middle school appropriate is important.

Another major finding was that students generally felt positively about STEM learning, and inquiry and project-based learning strategies. From both qualitative classroom observations and student interviews, most students reacted positively to these learning investigations even when the investigations pushed them to meet high expectations, or learn about topics that were new or multifaceted. These observations also highlight the importance of scaffolding and appropriate teacher support during high-cognitive learning investigations so that students feel supported yet free to struggle in positive ways (Anderman & Sinatra, 2012).

An additional major finding was the impressive Cognitive Skills (issue identification, issue analysis, and action planning) scores for students in this study. Cognitive skills were a measured component on the Middle School Environmental Literacy Survey (MSELS); the MSELS was used as a pretest and posttest. Students outscored every national age category (6th, 7th and 8th grade) on both the pretest and posttest for Cognitive Skills. Issue identification, analysis and action planning are key steps in the engineering design process utilized by many classes at the study's site school. Furthermore, this finding highlights the competitiveness of STEM-based curriculum that is integrated across all curricular contents and grade levels at the study's school site. Students in this study were competitive (according to MSELS scores) with schools that employ an exemplary environmental education curriculum identified in national studies.

Lastly, one of the major components of environmental literacy is behavior. Behavior (as measured by the MSELS) includes the actual commitment of students following through on pro-environmental behaviors in their daily lives. According to MSELS data, students in this study have lower than typical scores for Behavior on both pretest and posttest. These lower scores were much lower than anticipated and lower than national data trends, too. Behavior scores (pretest= 30.79 and posttest=29.0) still ranked “moderate” nationally; however, all national age groups (6th, 7th and 8th grade) outscored students in this study.

Expected outcomes. One expected outcome of this study was the value in using a mixed methods research paradigm. The literature indicated that quantitative tools like the MSELS alone, cannot correctly measure the actual changes in the environmental literacy of middle school students; furthermore, qualitative instruments such as classroom observations and interviews are needed to fully grasp any changes in environmental literacy (Creswell, 2014, p. 19). Utilizing a combination of qualitative and quantitative while allowing the synthesis from the entire data set, was important in gauging not only the changes in environmental literacy, but more importantly, the how or why these changes occurred. In this study specifically, if only the quantitative data is used, it appears that there was not positive growth when STEM-based learning is used; however, when looking at the entire data set and including qualitative student interviews and classroom observations, there are many positive outcomes when STEM-based learning is used to impact the environmental literacy of middle school students.

Unexpected outcomes. Because there are no studies in existence that measure the environmental literacy of students in the state in which the study took place, it was challenging to expect any certain outcomes. So there were many more unexpected outcomes than anticipated. First, I was expecting a greater increase in overall environmental literacy when comparing the pretest and posttest. It was unexpected that there would be a decline at all, even though this decline was slight and not statistically significant, it was still slightly disappointing because there were few gains overall. The treatment period for this study was only four weeks, results might vary much more if the posttest was given at the end of the students' school year. Comparing this study's data to national 6th and 8th grade data, students scored higher than both of these groups. Sixth graders scored 143.99/240, the study's 7th graders scored 149.8/240 (posttest), and the 8th graders scored 140.19/240. When compared to only the second phase of the MSELS which measured 7th graders from schools that had established an exemplary environmental education program, these national 7th graders scored 151.65/240. One major factor in this was that students scored higher (and much lower) in certain areas of the pretest compared to national data trends. Qualitative data gave a greater sense of support and appreciation of STEM-based learning for middle school students because they indicated that they both enjoyed and learned from project and inquiry-based learning during this study.

Even though this study took place at an established STEM school where students are asked to analyze the nature of problems they are trying to solve by designing different solutions, not all students that attend the study school enroll because of the STEM curriculum. This means that a portion of the students attend the study school because they live within the school's attendance zone. Students in this study scored higher than national data for all grade levels in the area of Cognitive Skills which includes issue identification, issue analysis and action planning. Again, these skills are essential in many of the engineering activities that students participate in during their 6th, 7th and 8th grade years; however, it was unexpected that students would outscore so strongly compared to national data. This observation could be a larger implication of the integration of STEM-based curriculum during these students' 6th grade year at the study school. National data trends illustrate that this category (Cognitive Skills) is typically the lowest (McBeth et al., 2011).

Another category that yielded surprising results was the Behavior category. This category was measured by 12 items on the MSELS and student interview questions. Usually there is some sort of correlation between students' Environmental Affect and their Behavior; students generally commit to positive environmental behaviors yet do not always follow through on those commitments (McBeth et al., 2011, p. 5-7). Nationally, 6th graders have a 2.29 point discrepancy between Environmental Affect and Behavior, 7th graders have a 1.25 point discrepancy, 8th graders have a 2.92 point discrepancy. In this study, students had a 10.57 point discrepancy for their pretest, and a 12.1 discrepancy for their posttest; this illustrates that there is greater contrast in the study's students making positive choices about the environment as compared to national data. The Behavior scores were much lower than expected based off of the national data trends. As literature indicates, the discrepancy between commitment to act and the actual behaviors that take place is a complex field of research (Hungerford & Volk, 1990; Kollmuss & Agyeman, 2002). I think these complications are further impacted by the complex world of middle school development.

Limitations

Even with careful planning, action-research studies have limitations, and it is essential that these limitations are carefully examined before, during and after the study takes place. This study's timeline began approximately four days after the start of a new school year. Despite the best efforts of the researcher, the classroom was still in the early stages of developing relationships, and setting classroom expectations and procedures; because of this, students were actively learning how to inquire about scientific and environmental concepts and complete hands-on learning investigations within the means of the classroom expectations. Conversely, if these learning activities would have occurred towards the end of the school year, students would be well versed in inquiry and project-based learning methods; therefore, their higher comfort level might have yielded different results. Furthermore, students were asked to do multiple higher-order thinking activities and metacognitive processing activities as they transitioned back into the routine of school from their summer breaks. I predict that if the same instructional strategies (STEM, environmental, inquiry and project-based) were used throughout the year, scores in all MSELS components would climb to match the national 7th grade data. I found that these strategies were easily implemented, and generated positive student feedback; I plan to continue implementing these strategies.

Another limitation was within the MSELS instrument itself. It was robust with 75 questions (only four being demographic in nature) and took students on average between 23.4 minutes (pretest) and 20.0 minutes (posttest) to complete. Paired with providing directions, students took up an entire class hour taking the MSELS. The instrument was designed to be completed within a 50-minute time period and rated at a reading level associated with middle school grades (McBeth et al., 2011, p. 18). Certain sections required student to read passages and answer questions based off of these passages and in order to compare data nationally, the MSELS could not be modified to meet the individualized educational plans for students with special needs, including learning disabilities or cognitive delays. Modifications might have included eliminating answers, having the test read outloud, and having an adult mark answers. The case managers for these students were consulted as to whether the students should or should not take the MSELS; if the case manager said the student should not, the student did not take the MSELS and the data from this instrument was not measured. There were 146 students that had provided consent for the study’ however, 131 students were able to take the MSELS due to the special education requirements. Students were able to access a printed copy of the longer reading passages; however, few students did. In addition, three students did not participate in the posttest because they were absent on the day of the MSELS; the scope and sequence of the class as a whole, did not allow MSELS make-ups.

Another limiting component of the MSELS instrument was some questions did not model authentic behavior action steps for middle school students. For example, one question asked students if they had written someone about a pollution problem; however, middle school students might rely more on social media communications versus written communications regarding pollution. Students in this study indicated that they relied on the Internet and social media to gain information about the environment and problems. Furthermore, another survey question asked if students had spoken to their parents about not purchasing animal fur products. If students themselves did not own animal fur products (nor their family members), answering that they had not asked counted against their Behavior component score, even if they did not have to ask because their parents did not own fur or were not financially able to purchase fur in the first place.

Another limitation of this study was that intermixed with the STEM-themed learning investigations were skill-based instructional days which included teaching about experimental design. This occurred towards the end of the study period, three days before the posttest.

Examples for this teaching time were not environmentally-based which might have impacted the results because it occurred at the end nearest the posttest.

Lastly, the treatment period of intensive environmental STEM-themed investigations covered four weeks. This is not a tremendous time to measure changes in environmental literacy. Possibly within a longer time period, the environmental literacy components could be better measured. I think a grander research study would assess environmental literacy at the beginning of a school year and compare data to environmental literacy at the end of the year after a school year of environmental STEM-themed investigations. This future research question would begin to gather more evidence to the impacts of inquiry-based, project-based STEM learning initiatives.

I still feel that the MSELS was the best (and only national) instrument to measure the environmental literacy of the study's target audience. Other states have developed their own tools to measure; however, our state has not and thus has no comparable data. Being able to compare data to national trends was helpful, especially for comparing our STEM school's results to schools that employ an exemplary environmental education program as measured by phase 2 of the MSELS. Despite the limitations identified in this section, the study and national data sets were helpful in understanding the various factors that contribute to environmental literacy, especially at the middle school level.

Connections with the Literature

The literature on the topics of middle school students, environmental literacy and STEM education provided the basis for my understanding of how these topics are related and unrelated. There are many pieces of literature that explain the various components of this study;

however, none that relate the state's environmental literacy for this age group. This hole in the literature left many assumptions to be made regarding how well the national environmental literacy data for middle school students would compare to the study school's data. Despite not having localized environmental literacy data, there are a great amount of literature resources that outline the importance of middle school learners, STEM education and environmental literacy.

Armstrong (2006) explained how vastly different middle school learners are because of their developing skills in thinking, posing solutions to problems and making decisions, and the challenges that puberty and brain development have in further complicating their abilities to engage in problem-solving. The STEM-based learning investigations required students to engage in project-based and inquiry-based learning strategies which can be difficult, and challenging to students. This was best illustrated when students needed to decide different factors as part of their learning investigations throughout the study period. Students remarked that it was challenging and time-consuming to make the choices necessary to begin work on various parts of the learning investigations; these observations were corroborated by classroom observations, too. From my observations, the social dynamics of collaborative group work makes this especially challenging in the middle school classroom. Anderman and Sinatra (2012) noted that even with the challenges of these instructional strategies, they allow students to employ the critical thinking skills that middle schoolers are developing. With these learning strategies, the teacher's role drastically changes from teacher-centered to student-centered (Savery, 2015, p. 16); however, the teacher still has an essential role in scaffolding learning experiences so that students feel a certain level of success and support (Witt & Ulmer, 2010, p. 272). In this study, scaffolding was important because students, especially at the beginning of a school year, wanted to know what was expected and unexpected. In addition, students wanted the support that the teacher and scaffolding provides as students navigate new learning experiences and investigations.

The history of STEM education is unique and unexpected because it is rooted in maintaining a competitive national workforce for STEM careers (Kuenzi, 2008) and to compete with other countries. Green STEM connects young problem solvers to local issues that directly impact their communities (Arndt & Tweed, 2015) and provides a great union of the benefits of STEM learning and the environmental focus needed to develop environmental literacy in students (Hoepfl, 2015). Environmental literacy became the outcome of environmental education initiatives as outlined by the Tbilsi Conference Declaration (Hungerford & Volk, 1990), and provided points of connection for students to identify and pose resolutions to environmental issues facing today's generation (McBeth & Volk, 2009, p. 56). The importance of environmental literacy is well supported by the research because being environmentally literate combines taking issue with the concerns of the environment while being knowledgeable, skillful and motivated to discover solutions to environmental problems with a heightened focus on prevent the problems in the future (NAAEE, 2000/2004).

The most helpful literature involved the MSELS as a measurement tool for this research study. Both phase 1 and 2 calculated national averages for 6th and 8th grade students, and 7th grade averages for students that attend schools with an exemplary environmental education program (McBeth et al., 2011). Without being able to compare my data to these national averages, I would not have known if the study's results were significant or not. The national scope of phase 1 and phase 2 was immense yet provided key data for this study and future studies in the field of environmental literacy.

There are connections between my research project and the literature. Middle schools are a complex educational audience; this adolescent development period is a time marked with vast changes from cognitive brain development to social and relational changes (Ernst et al., 2006). These complex changes are evident from classroom observations where students struggled to make decisions, and arrive at consensus when planning investigations and designs. For some students, it was tough to navigate the social requirements of working together and communicating. Despite these challenges, it is important to place students in the role of making decisions and critically thinking (Anderman & Sinatra, 2012) about the environmental problems posed in the study's investigations.

In general, students in the study felt positively towards the environment in both learning about environmental topics and in verbally committing to pro-environmental behaviors, as measured by the MSELS and student interviews. These observations pair with national data trends as students had positive feelings regarding the environment and their actions (McBeth et al., 2011, p. 7). According to the student interviews, students all noted positive outcomes from the learning investigations towards their own feelings about the environment and especially on why learning about the environment was important. Also noted in the study's data, was the disconnect between students' knowledge about the environment, their intention to act positively towards the environment, and their actual, measured follow-through on these positive behaviors. This is visible in national data trends; however, more importantly, students feeling positively towards the environment is an indicator of students taking positive actions towards their own behavior regarding the environment (McBeth et al., 2011, p. 5).

The literature does support my study's observations of their overall environmental literacy scores; furthermore, students receiving one year of STEM-themed curriculum that crosscuts different content areas does seem to indicate higher scores in the areas of Cognitive Skills which includes issue identification, issue analysis and action planning. This area was much lower in national data trends, even those schools that employ a strong environmental education curriculum.

Looking Forward

According to MSELS and student interviews, students had a positive outlook on how and why the environmental was important; this garners much hope in regards to the value that students find in learning about the environment and the challenges that accompany STEM-based learning. There are implications of this research on teaching as a whole, the lack of statewide data to gauge if students are becoming environmentally literate, and the positives of using STEM-based learning to reach students.

Environmental literacy, as a whole, is composed of much more than only having knowledge about environmental topics and issues; knowledge alone cannot produce citizens that are environmentally literate (Hungerford & Volk, 1990). In this study, little time was spent explicitly teaching about the environment and still, the study yielded a slight positive growth in the component of Ecological Knowledge. It is important that students understand the content knowledge needed to participate in learning investigations about those topics; however, learning to promote environmental literacy must extend beyond memorizing scientific facts or lacking the understanding of how facts connect to each other and connect to environmental problems.

Another implication of this research study, is questioning if STEM-based learning (including the inquiry and project-based learning investigations in this study) has the same impacts that environmental education curriculum components such as using nationally-developed Project WET/WILD/PLT, partnering with federal and regional programs, and integrating environmental education as an approach to learning (McBeth et al., 2011, p. 39). There are established and nationally respected environmental education curricular options including Project WET, Project WILD and Project learning tree that provide accessible learning activities to implement in the classroom (McCrea, 2006) that can positively influence learning. These environmental education curriculum components were the basis for the 7th grade national data gathered for phase 2 of the MSELS; students data from this study compared closely in the areas of environmental affect and cognitive skills, but different in the areas of environmental knowledge and behavior. If using these two different instructional strategies (STEM-based learning and environmental education) offer the same impacts, this implies that both would positively impact students at the middle school level. For some schools, one strategy might be easier to employ for teachers and for students based on accessibility to environmental education, and financial requirements of either STEM-based learning or environmental educational opportunities.

This study's results do further illustrate the existence of a discrepancy between environmental affect (intention to act) and behavior (actually taking action). This trend is nationally recognized, too (McBeth et al., 2011). Generally, pro-environmental behavior can be predicted by how sensitive an individual is to the environment (Hungerford & Volk, 1990). National data illustrates that younger students are generally more positive towards the environment and commit to pro-environmental behaviors and follow-through on these commitments (McBeth et al., 2011). Environmental literacy reflects the complex limitations surrounding communities such as growing personal beliefs, complex experiences, new social dynamics and environmental issues that arise, change and develop (Hollweg et al., 2011). This implies that students need to feel connected to their environment in order to both commit to pro-environment behavior choices and then follow through with those behavior commitments.

There is a need for further research in the areas of environmental literacy in this state, specifically because there are no current measures of this at all. "Direct responses to global environmental problems can slow the tide of environmental degradation, but reversing the trend requires an environmentally literate citizenry" (Stevenson et al., 2013, p. 1). Because the need for environmental literacy in learners is important and many of the environmental problems require critical and creative thinking (NSTA, 2003), having a more significant basis of literature regarding the connections between these two topics is essential in order to make policy in regards to what students should and should not be learning in school settings and the value of these learnings. In addition, the relationships between experience and age in regards to understanding how students feel about the environment and why or how they behave towards the environment are necessary. Student interviews in this study illustrated how different students' outdoor experiences range from unstructured play time or structured time included organized sports, research could explore the implications of this time in specific regard for middle school learners.

After committing time to researching, developing and carrying out this research project, I take great value in the outcomes and data analysis. This research highlighted the common missions among the different styles of education delivery as they relate to promoting the development of environmental literacy, including STEM-based, inquiry-based, project-based and environmental education. Often I feel that I do not bring my students outdoors frequently enough and that I do not have opportunities as a classroom educator to promote the learning goals of environmental education; however, there are different ways of approaching this goal of developing environmental literacy. The learning strategies (STEM-based, project-based, inquiry-based and environmental education) are different yet connected. STEM-based learning with an environmental focus that uses inquiry and project-based learning is an effective way to develop the cognitive skills necessary to understand environmental problems and the problem-solving skills needed to pose solutions or preventions to these problems. Even without taking students outdoors, students noted during interviews that they felt more positive towards the environment. This is important because taking students outdoors helps students feel connected to the environment (White, 2008). Furthermore, their raw averages on the MSELS posttest grew in the areas of environmental sensitivity and how they felt about the environment.

The basis of this entire research project was to understand how STEM-based learning can impact the environmental literacy of middle school students. Learning investigations employed Green STEM, where local environmental problems were of focus instead of global problems that might not be impactful in the students' foci of control (Arndt & Tweed, 2015). Through the study, students maintained the cognitive skills (issue identification, issue analysis and action planning) needed to analyze these local problems and pose solutions or preventions, and students responded positively when asked if these investigations helped them understand the environment. Green STEM is a powerful teaching lens to use in facilitating life science standards because it promotes critical thinking and connects students to their local communities, and it will be a strategy I further use within my classroom to promote students' awareness of local environmental problems that are within their realm of analyzing and posing solutions or preventions.

Communicating with others. The original intent of this capstone research project was to create a deeper understanding of what environmental literacy is and comprehend how the different components of environmental literacy are impacted by what happens in and out of a middle school science classroom. Environmental literacy is both complex and essential; however, the role of environmental literacy in schools can be complicated because many parts of environmental literacy deal with behaviors. As a classroom teacher, I often feel guilty because I do not take students outside frequently enough for them to create meaningful relationships with their natural surroundings that can positively influence their environmental literacy; however, I also understand that there are many ways to create connections with the environment. Environmental literacy has four major components, and I wanted to recognize, through this research, that there are still classroom-based activities that can positively promote a strong environmental literacy in students when going outside is not feasible. This research project has already positively impacted my school committee work, because I have been able to lend a stronger voice, poised in research and a broad awareness of best practices, to school-wide decisions being made regarding our STEM program. Historically, I have not been afraid to speak up in order to make the best student-centered decisions for both my classroom and school; however, now I can confidently speak to what I have been researching and immersing myself in for this capstone research project. I plan to share my work with both teachers and administrators in formal meetings and informal (classroom conversations, PLC meetings) ways so that many more educational professionals can benefit from this research.

Furthermore, this capstone research project has been one of the best education models for the scientific method I have used within my own classroom. I have been very honest with students throughout this process of how important research is to create understanding and meaning in the experiments we do; students have been enamored with this process because it is so centered around them. I have appropriately shared the different requirements of this capstone process and will share my findings with my students (the research subjects of this project) once they are finalized. As my students move through their science fair projects, they typically struggle with the unexpected challenges or problems that arise when doing research, and it has been positive to share with them my own experiences of struggle and persistence during my own research encounters.

Unexpectedly, I became a team member on a school district committee regarding energy usage and consumption which resulted in updating our district's energy policy. Part of this process is to include students in the process of understanding energy usage and how our behaviors contribute to wasteful energy consumption and increased district spending. My research has been influential in my contributions to this process, because I am able to reaffirm what the program's engineers find regarding promoting better energy usage, and speak to ways to include students in positively influencing our school's energy usage footprint.

Lastly, one of the more important communication plans is to advocate for STEM, environmental, inquiry and project-based learning in classrooms. Through this research, I have identified the powerful impacts these strategies have on students, and I am proud to talk about my experiences with pretty much anyone that listens to me because I have developed such a passion for this style of learning facilitation. I do have plans to create an article to submit for publication and organize a presentation for a conference. I have presented before at science teacher conferences, and I think it is a great way to connect with other teachers both sharing my learnings and learning from others.

Summary

In this chapter, the outcomes of this research project were closely examined. The expected and unexpected outcomes of the research plan, data and observations, and major learnings were focused on while identifying any limitations that might impact the outcomes of this research study and others like it. The literature used to document the need for a study of this sort and plan the research project was reviewed with major focus on middle school learners, STEM education and environmental literacy. Connections were drawn between the literature and the outcomes of the research project. Lastly, implications in regards to classroom benefits, future study areas and how useful this study proved to be were considered.

REFERENCES

Al-Balushi, S. M., & Al-Aamri, S. S. (2014). The effect of environmental science projects on students' environmental knowledge and science attitudes. *International Research in Geographical and Environmental Education*, *23*(3), 213-227.

American Association for the Advancement of Science, Project 2061. (1995). *Science for all Americans summary*. Washington, DC: American Association for the Advancement of Science.

Anderman, E. M. & Sinatra, G. M. (2012). The challenges of teaching and learning about science in the twenty-first century: Exploring the abilities and constraints of adolescent learners. *Studies in Science Education*, *48*(1), 89-117.

Armstrong, T. (2006). *The best schools: How human development research should inform educational practice*. Alexandria, VA: Association for Supervision and Curriculum Development.

Arndt, L., & Tweed, A. (2015, Spring). Green STEM: STEM as it's meant to be. Retrieved from http://www.advanc-ed.org/source/green-stem-stem-its-meant-be

Arzy-Mitchell, B. K. (2013). Brain-based learning for adolescent science students: A review of the literature. *Doctoral Projects, Masters Plan B, and Related Works*. Paper 12.

Aulls, M. W. (2002). The contributions of co-occurring forms of classroom discourse and academic activities to curriculum events and instruction. *Journal of Educational Psychology*, *94*, 520-538.

Barcelona, K. (2014). 21st century curriculum change initiative: A focus on STEM education as an integrated approach to teaching and learning. *American Journal of Educational Research*, *2*(10), 862-875.

Basham, J. J., Israel, M., & Maynard, K. (2010). An ecological model of STEM education: operationalizing STEM for all. *Journal of Special Education Technology*, *25*(3), 9-19.

Becker, K., & Park, K. (2011). Effects of integrative approaches among science, technology, engineering, and mathematics (STEM) subjects on students' learning: A preliminary meta-analysis. *Journal of STEM Education: Innovations and Research*, *12*(5/6), 23.

Bodor, S. (2015, December 9). NAAEE hails history-making opportunities for environmental learning. Retrieved from http://www.prweb.com/releases/2015/12/prweb13120108.htm

Breiner, J. M., Harkness, S. S., Johnson, C. C., & Koehler, C. M. (2012). What is STEM? A discussion about conceptions of STEM in education and partnerships. *School Science and Mathematics, 112*(1), 3-11. doi:10.1111/j.1949-8594.2011.00109.x

Bybee, R. W. (2013). *Case for STEM education: Challenges and opportunities*. National Science Teachers Association.

Chen, C. H., & Howard, B. (2010). Effect of live simulation on middle school students' attitudes and learning toward science. *Educational Technology & Society*, *13*(1), 133-139.

Christensen, R., Knezek, G., & Tyler-Wood, T. (2015). Alignment of hands-on STEM engagement activities with positive STEM dispositions in secondary school students. *Journal of Science Education and Technology*, *24*(6), 898-909.

Crawford, G. B. (2007). *Brain-based teaching with adolescent learning in mind*. Thousand Oaks, CA: Corwin Press.

Creswell, J. W. (2014). *Research design: Qualitative, quantitative, and mixed methods approaches (4th edition).* Thousand Oaks, CA: SAGE Publications.

Doppelt, Y., Mehalik, M. M., Schunn, C. D., Silk, E., & Krysinski, D. (2008). Engagement and achievements: A case study of design-based learning in a science context. *Journal of Technology Education, 19*(2), 22-39.

Dorie, B., Jones, T., Pollock, M., & Cardella, M. (2014). Parents as critical influence: Insights from five different studies. *School of Engineering Education Graduate Student Series*. Paper 55.

Ernst, M., Pine, D. S., & Hardin, M. (2006). Triadic model of the neurobiology of motivated behavior in adolescence. *Psychological Medicine*, *36*(3), 299-312.

Fisher, D. D., & Frey, N. N. (2014). STEM for citizenship. *Educational Leadership, 72*(4), 86-87.

Geier, R., Blumenfeld, P. C., Marx, R. W., Krajcik, J. S., Fishman, B., Soloway, E., & Clay-Chambers, J. (2008). Standardized test outcomes for students engaged in inquiry-based science curricula in the context of urban reform. *Journal of Research in Science Teaching*, *45*(8), 922-939.

George, P., Stevenson C., Thomason, J., & Beane, J. (1992). *The middle school and beyond.* Alexandria, VA: Association for Supervision and Curriculum Development.

Harmer, A. J., & Cates, W. M. (2007). Designing for learner engagement in middle school science: Technology, inquiry, and the hierarchies of engagement. *Computers in the Schools*, *24*(1-2), 105-124.

Hmelo-Silver, C. E., Duncan, R. G., & Chinn, C. A. (2007). Scaffolding and achievement in problem-based and inquiry learning: A response to Kirschner, Sweller, and Clark (2006). *Educational Psychologist*, *42*(2), 99-107.

Hoepfl, M. (2016, November 5). Teaching and learning in project-based learning, technology and engineering education, and related subjects. *Mississippi Valley Technology Teacher Education Conference*. Retrieved from http://www.mississippivalley.org/wp-content/uploads/2015/12/Hoepfl.pdf

Holdren, J. P., Marrett, C., & Suresh, S. (2013). Federal science, technology, engineering, and mathematics (STEM) education 5-year strategic plan. *National Science and Technology Council: Committee on STEM Education*.

Hollweg, K. S., Taylor, J. R., Bybee, R. W., Marcinkowski, T. J., McBeth, W. C., & Zoido, P. (2011). Developing a framework for assessing environmental literacy. *Washington, DC: North American Association for Environmental Education*.

Honey, M., Pearson, G., & Schweingruber, H. A. (2014). *STEM integration in K-12 education: Status, prospects, and an agenda for research*. Committee on Integrated STEM Education; National Academy of Engineering; National Research Council. doi:10.17226/18612

Hungerford, H. R., & Volk, T. L. (1990). Changing learner behavior through environmental education. *The Journal of Environmental Education*, *21*(3), 257-270.

Hungerford, H. R., Volk, T. L., McBeth, W. C., & Bluhm, W. J. (2009). Middle School Environmental Literacy Survey. Carbondale, IL: Center for Instruction, Staff Development, and Evaluation.

Kirschner, P. A., Sweller, J., & Clark, R. E. (2006). Why minimal guidance during instruction does not work: An analysis of the failure of constructivist, discovery, problem-based, experiential, and inquiry-based teaching. *Educational Psychologist*, *41*(2), 75-86. doi:10.1207/s15326985ep4102_1

Knezek, G., Christensen, R., Tyler-Wood, T., & Periathiruvadi, S. (2013). Impact of environmental power monitoring activities on middle school student perceptions of STEM. *Science Education International*, *24*(1), 98-123.

Kollmuss, A., & Agyeman, J. (2002). Mind the gap: Why do people act environmentally and what are the barriers to pro-environmental behavior?. *Environmental Education Research*, *8*(3), 239-260.

Kolodner, J. L., Camp, P. J., Crismond, D., Fasse, B., Gray, J., Holbrook, J., … Ryan, M. (2003). Problem-based learning meets case-based reasoning in the middle-school science classroom: putting learning by design™ into practice. *The Journal of the Learning Sciences, 12*(4), 495–547.

Krajcik, J., Blumenfeld, P., Marx, R., Bass, K., Fredricks, J., & Soloway, E. (1998). Inquiry in project-based science classrooms: Initial attempts by middle school students. *Journal of the Learning Sciences, 7*(3), 313-350.

Kuenzi, J. J. (2008). *Science, technology, engineering, and mathematics (STEM) education: Background, federal policy, and legislative action*. Congressional Research Service Reports. Paper 35.

Landers, P., Naylon, M., & Drewes, A. (2002). *Environmental literacy scope and sequence: Providing a systems approach to environmental education in Minnesota*. Minnesota Office of Environmental Assistance.

Littledyke, M. (2008). Science education for environmental awareness: Approaches to integrating cognitive and affective domains. *Environmental Education Research, 14*(1), 1-17. doi:10.1080/13504620701843301.

Manning, M. L., & Bucher, K. T. (2005). *Teaching in the middle school*. Upper Saddle River, NJ: Pearson/Prentice Hall.

McBeth, W., & Volk, T. L. (2009). The national environmental literacy project: A baseline study of middle grade students in the United States. *The Journal of Environmental Education, 41*(1), 55-67. doi:10.1080/00958960903210031

McBeth, W., Hungerford, H., Marcinkowski, T., Volk, T., & Meyers, R. (2008). National environmental literacy assessment project: Year 1, national baseline study of middle grade students. Washington, DC: National Oceanic and Atmospheric Administration. Retrieved from: http://ver2.oceanleadership.org/wp-content/uploads/2009/08/environmental-literacy.pdf

McBeth, W., Hungerford, H., Marcinkowski, T., Volk, T., & Cirfranick, K. (2011). National environmental literacy assessment project: Year 2, measuring the effectiveness of north american environmental education programs with respect to the parameters of environmental literacy. Washington, DC: National Oceanic and Atmospheric Administration. Retrieved from: http://www.oesd.noaa.gov/outreach/reports/NELA_Phase_Two_Report_020711.pdf

McBride, B. B., Brewer, C. A., Berkowitz, A. R., & Borrie, W. T. (2013). Environmental literacy, ecological literacy, ecoliteracy: What do we mean and how did we get here? *Ecosphere*, *4*(5), 67. http://dx.doi.org/10.1890/ES13-00075.1

McCrea, E. (2006). *The roots of environmental education: How the past supports the future*. Stevens Point, WI: University of Wisconsin-Stevens Point and the Environmental Education and Training Partnership.

Mills, G. E. (2014). *Action research: A guide for the teacher researcher (the 5th edition)*. Upper Saddle River, NJ: Pearson Education.

Moseley, C. (2000). Teaching for environmental literacy. *The Clearing House: A Journal of Educational Strategies, Issues and Ideas*, *74*(1), 23-24.

Mueller, D. (2014). *Gender: A cradle to career perspective*. Saint Paul, MN: Wilder Research.

Murphy, T. P., & Olson, A. M. (2008). *The third Minnesota report card on environmental literacy: A survey of adult environmental knowledge, attitudes and behavior*. Minnesota Pollution Control Agency.

National Research Council. (2011). *Successful k-12 STEM education: Identifying effective approaches in science, technology, engineering, and mathematics*. Committee on Highly Successful Science Programs for K-12 Science Education. Board on Science

Education and Board on Testing and Assessment, Division of Behavioral and Social Sciences and Education. Washington, DC: The National Academies Press.

National Research Council. (2012). *A framework for k-12 science education: Practices, crosscutting concepts, and core ideas. Committee on a Conceptual Framework for New K-12 Science Education Standards*. Board on Science Education, Division of Behavioral and Social Sciences and Education. Washington, DC: The National Academies Press.

National Science Board. (2014). Science and engineering indicators, 2014. Arlington VA: National Science Foundation. (NSB 14-01).

NEEF. (2015) *Environmental literacy in the United States: An agenda for leadership in the 21st century*. Washington, DC: National Environmental Education Foundation.

NGSS Lead States. (2013). Next generation science standards: For states, by states. Washington, DC: The National Academies Press.

North American Association for Environmental Education (NAAEE). (2000/2004). Excellence in environmental education: Guidelines for learning (K-12). Washington, DC: NAAEE.

NSTA Board of Directors. (2003, February). NSTA position statement: Environmental education and science education for middle level students. Retrieved from http://www.nsta.org/about/positions/environmental.aspx

Olson, S., & Riordan, D. G. (2012). Engage to excel: Producing one million additional college graduates with degrees in science, technology, engineering, and mathematics. Report to the President. *Executive Office of the President*.

Organisation for Economic Co-operation and Development., & Programme for International Student Assessment. (2009). *Green at fifteen?: How 15-year-olds perform in environmental science and geoscience in PISA 2006*. Paris: OECD.

Ramsey, J., Hungerford, H. R. & Tomera, A. N. (1981). The effects of environmental action and environmental case study instruction on the overt environmental behavior of eighth-grade students. *Journal of Environmental Education*, *13*(1), 24-29.

Roth, C. E. (1992). Environmental Literacy: Its roots, evolution, and directions in the 1990s. Columbus, OH: ERIC/SMEAC Information Reference Center.

Sanders, M. (2009). STEM, STEM education, STEMmania. *Technology Teacher*, *68*(4), 20-26.

Savery, J. R. (2015). Overview of problem-based learning: Definitions and distinctions. *Essential Readings in Problem-Based Learning: Exploring and Extending the Legacy of Howard S. Barrows*, 5-15.

Schuck, J. A., DeHaan, R. L., & McCray, R. A. (Eds.). (2003). *Improving undergraduate instruction in science, technology, engineering, and mathematics: Report of a workshop*. National Academies Press: Chicago.

Soper, E., Fano, E., & Hammonds, J. (2015). *Green STEM: How environment based education boost student engagement and academic achievement in science, technology, engineering, and math*. Reston, VA: National Wildlife Federation.

Stevenson, H. J. (2014). Myths and motives behind STEM (science, technology, engineering, and mathematics) education and the STEM-worker shortage narrative. *Issues in Teacher Education*, *23*(1), 133.

Stevenson, K. T., Peterson, M. N., Bondell, H. D., Mertig, A. G., Moore, S. E. (2013). Environmental, institutional, and demographic predictors of environmental literacy among middle school children. PLOS ONE, 8(3), 1-11. doi:10.1371/journal.pone.0059519

Tai, R. H., Qi, Liu C., Maltese, A. V., & Fan, X. (2006). Planning early for careers in science. *Science, 312*(5777), 1143-1144.

Tbilisi Conference Declaration. (1978, January). *UNESCO-UNEP Environmental Education Newsletter, 3*, 1-8.

Utarasakul, T. (2008). An enhancement of environmental awareness for undergraduate students by using holistic classroom activities. *Journal of Environmental Research And Development*, *3*(1), 285-291.

Verma, A. K., Dickerson, D., & McKinney, S. (2011). Engaging students in STEM careers with project-based learning—MarineTech project. *Technology and Engineering Teacher, 71, 25-31.*

White, H. (2008). Connecting today's kids with nature. Reston, WV: National Wildlife Federation. Retrieved from https://www.nwf.org/pdf/Faces%20of%20NWF/CKN_full_optimized.pdf

Witt, C., & Ulmer, J. (2010). The impact of inquiry-based learning on the academic achievement of middle school students. *Proceeding of the 29th Annual Western Region AAAE Research Conference,* 269-282.

Wolf, S. J., & Fraser, B. J. (2008). Learning environment, attitudes and achievement among middle-school science students using inquiry-based laboratory activities. *Research in Science Education*, *38*(3), 321-341.

Zalaznick, M. (2015, October). Environmental education digs deep: Projects in great outdoors among the best ways to teach skills that cut across curriculum. *District Administration*, *51*(10), 46.

APPENDIX A

Learning Plan

Day 1	Day 2	Day 3	Day 4	Day 5
Administer the MSELS (pre test)	Nature walk with observations	IV #1: Introduce the Characteristics of Life, microscopes as scientific tools	Why is water important inquiry--	IV #2: Environmental issue brainstorm, discuss the learning mission
Day 6	**Day 7**	**Day 8**	**Day 9**	**Day 10**
Research the chosen environmental issue, plan PSA video or poster	Work day, teacher-group conferences	Present PSA video or poster to class, reflection	IV #3: Present students with environmental engineering problem, research and plan solution	Construct and test solutions
Day 11	**Day 12**	**Day 13**	**Day 14**	**Day 15**
Test and improve solutions	Final data gathering, reflection	Introduce metric conversions and measurements	Practice metric conversion and measurements	Introduce the scientific method, practice
Day 16	**Day 17**	**Day 18**	**Day 19**	**Day 20**
Introduce experimental variables, practice	IV #4: research and plan	Gather data for investigation 4	Prepare experiment conclusion, reflect	Administer the MSELS (post test)

Learning plan outlining the instructional and investigative components of the study. On day 1 and 20, the MSELS was administered. IV represents the investigation number within the sequence of learning. Investigation #1 (IV #1) lasted two full class days; IV #2 lasted four days; IV #3 lasted four days; IV #4 lasted three days.

APPENDIX B

Middle School Environmental Literacy Survey Permission Letter

Center for Instruction, Staff Development and Evaluation
1925 New Era Road
Carbondale, IL 62901

Email: cisde@midwest.net *PH: 618-457-8927*

May 3, 2016

Megan Heitkamp
11973 Cran St. NW
Coon Rapids, MN 55448

Dear Megan:

This letter constitutes permission for you to use the Middle School Environmental Literacy Survey in your thesis research. Please cite the instrument in the following manner: Hungerford, H.R., Volk, T.L., McBeth, W.C., & Bluhm, W.J. (2009). *Middle School Environmental Literacy Survey*. Carbondale, IL: Center for Instruction, Staff Development, and Evaluation.

Your study will investigate the impacts of STEM investigations, project-based learning and inquiry-based learning on the environmental literacy of middle school students, using the online 2009 MSELS. You indicated that you plan to administer the MSELS to approximately 170 seventh-grade students before and following an intensive four weeks of STEM-based learning investigations. You also intend to compare your results to national baseline data from Phase One of NELA.

You have indicated that you will restrict access to the MSELS to those who are involved in the study or otherwise closely associated with your study. Thank you for that consideration. We prefer that you not include a copy of the instrument in any report. Rather, please indicate that the instrument cannot be distributed or used without permission from Hungerford, Volk, McBeth or Bluhm and provide contact information for us (cisde@midwest.net or mcbeth@uwplatt.edu).

We wish you continuing success as you carry out your study. Please do not hesitate to contact us if you have questions, or if there is some other way that we may be of help. We look forward to receiving a copy of your research report.

Sincerely,

Dr. Trudi Volk
Former Executive Director, CISDE
1925 New Era Road
Carbondale, IL 62901
PH: 618-457-8927
cisde@midwest.net

and
Emeritus Professor
Department of Curriculum and Instruction
Southern Illinois University
Carbondale, IL 62901

APPENDIX C

Investigation 1: Water Inquiry Name:

Inquiry Topic: Water	
Basic Facts:	Chemical Composition:
Pond Water Observations: sketch, label with total magnification and identify	
Inquiry Question: Why is Water Important to Living Things? Explain and include 1 colored drawing/sketch	

APPENDIX D

Investigation 2: Environmental Problem Project Name:

Mission: identify and research a local (in your own community) environmental problem. Brainstorm and develop a potential solution to this environmental problem. Create a public service announcement (1 minute or less) or design an informational poster about your problem and solution. You have three work days until your final PSA or poster is due. On day 2, classmates will conduct a peer-review of your work offering suggestions and constructive feedback to improve your project.

What is a local environmental problem and how might you solve or prevent it?

Required Items for the PSA or Informational Poster:

- ➔ What is the environmental problem?
- ➔ Why is this an environmental problem?
- ➔ What is a potential solution to this environmental problem?
- ➔ Why should people care about this problem and solution?
- ➔ What would change if this environmental problem improved?

PSA and Informational Poster Design Observations	
PSA Examples:	
Informational Poster Examples:	

Investigate and Brainstorm:

1. Environmental problem:

2. Facts and information about the problem:

3. Brainstorm solutions:

4. Why should people care about this environmental problem?

5. How will you explain the problem and solution to a general audience:

6. What might change if this environmental problem improved?

Plan: create a storyboard, script or rough outline of the key parts and design elements of your PSA or informational poster.

Grading Rubric:

Grading Element	4 (Proficient)	3 (Developing)	2 (Beginning)
Guidelines	All required items are included and accurate.	1 item is missing from the list of required items	2+ items are missing from the list of required items.
Audience Appeal	The project captures the audience's attention and maintains it throughout	The project captures the audience's attention, but does not maintain it consistently.	The project does not capture the audience's attention.
Message Effectiveness	The combination of creativity, technical skill and audience appeal deliver a clear message about the selected topic.	The intent of the project is understood, but it has little motivational value.	The message is not clear in the project.

Student predicted score: ____/12 *What improvements can you make to your project?*

APPENDIX E

Investigation 3: Wind Turbine Build Name:

Engineering Mission: our city needs to upgrade their wind turbine blades. The city's wind turbine generates power for about 100 homes and was built in 2001.

What type of wind turbine blades generate the most power?

Use your investigative skills to research wind turbine blade designs. Use the engineering design process to design, build and test your wind turbine blades.

- ➔ *Criteria*: turbine blades must attach to the provided hub, only use materials that are provided, need a minimum of two turbine blades, blades must freely rotate when attached to the turbine.
- ➔ *Constraints*: two days to build, test, improve and retest. Use the materials on the lab station.

Research about Wind Turbine Blades	
What variables or factors impact the power generated by wind turbine blades?	Research and compare/contrast the city's wind turbine blade design to other designs that are common in cities:
Wind Turbine Blade Engineering Design	
Brainstorm Design Features:	Sketch:
Fixes/Corrections (after testing):	Final Sketch:

Data Collection:

Voltage (V) Generated by Different Blade Designs			
Design Variable	Trial 1	Trial 2	Average

Class Observations: record any patterns you observed in both your data and the class data--

Reflection Questions:

1. Of your designs, which design generated the most voltage? ________________________

2. What problems came up as you worked towards your solution? How did you overcome these challenges?

3. The solution was to build a better wind turbine that generated more power than its' previous design; what environmental problem started this?

4. Imagine the wind turbines of the future--what might they look like and how might they impact the world?

APPENDIX F

Investigation 4: What Impacts Water Experiment Name:

Mission: use the scientific method/experimental design to investigate how different materials impact the quality of water. You can test up to three different materials to see the impacts of these materials of the water's pH.

How do different materials impact the pH of water?

Background Research:

What is pH?	
Why is water pH important?	
What happens if water is too acidic?	
What happens if water is too basic?	
How can pH be tested?	

Experimental Design:

1. My research question is:
2. My independent variable is:
3. My dependent variable is:
4. My three controlled variables (controls) are:
5. Hypothesis: If water
   ____, then the pH will
   ____, because
   ____
   ____
   ____.
6. Procedure:

7. Data Table:

8. Data Analysis: you can copy your graph from google sheets or Excel--

9. Conclusion:

APPENDIX G

Student Interview Questions

1. To you, what does environmental literacy mean?
2. How much time do you spend outside?
3. What are some activities you like to do outside?
4. What are some barriers that prevent you from going outside as much as you'd like?
5. Is the environment important? If so- why? If not- why not?
6. Does our community have environmental problems? If yes, what are some examples? If no, why not?
    a. Follow-up Question for #6 (if they say yes): How do you think we should go about changing the environmental problems in our community?
7. What skills should people have that fix or prevent environmental problems?
8. How do you think schools do providing a place to help you learn how to identify and solve environmental problems?
9. How did the water investigations impact your understanding of the environment?
10. How did the wind turbine design investigation impact your understanding of the environment?
11. How did the environmental problem PSA (public service announcement) investigation impact your understanding of the environment?
12. Have you experienced any behavior changes since these investigations? If so, what are some examples? If not, why not?
13. In the last week, how many times do you think you've:

a. Recycled paper at school in the recycling bin (not trash)?

b. Recycled plastic bottles at home or school?

c. Turned off the water when brushing your teeth?

d. Ate leftover food instead of throwing leftover food away?

e. Picked up litter outside when you saw it?

14. What are the most important things you have learned from the investigations?

APPENDIX H

Teacher Classroom Observations Graphic Organizer

Teacher Observations During Investigations	
Date:	Class Time:
Rate the level of engagement for students during structured work time: 1 2 3 4 5 (least engaged most engaged)	Observations:
Rate the level of student effort towards a solution to the environmental problem: 1 2 3 4 5 (least effort most effort)	Observations:
How smooth does the discussion/work appear to be for students: 1 2 3 4 5 (least smooth most smooth)	Observations:
What difficulties are students having during the investigation?	Examples:
How well can students tell the details regarding the environmental problem? 1 2 3 4 5 (zero details given complete details given)	Observations: