Spring 2017

The Impact Of Informal Education On Formal Education In Science A Symbiotic Relationship

Colin Johnson
Hamline University

THE IMPACT OF INFORMAL EDUCATION ON FORMAL EDUCATION IN SCIENCE

A SYMBIOTIC RELATIONSHIP

By

Colin Johnson

A Capstone submitted in partial fulfillment of the requirements for the degree of Master of Arts in Education: Natural Science and Environmental Education, Center for Global Environmental Education.

Hamline University

Saint Paul, Minnesota

May, 2017

Primary Advisor: Shelley Orr
Secondary Advisor: Benjamin Jones
Peer Reviewer: Celia McConnell

To my advisors, peer reviewers, coworkers, science professionals, and teachers. Thank you for your support throughout this Capstone process. I have become more informed about the needs of formal science teachers from my individuals that participated in my interviews and surveys. Analyzing the symbiotic relationship between formal and informal science educators is key in bringing more science and environmental careers in to this world.

"It is a wholesome and necessary thing for us to turn again to the earth and in the contemplation of her beauties to know the sense of wonder and humility."
- Rachel Carson

ACKNOWLEDGEMENTS

Special thanks to my individuals that shared their own experience and suggestions in formal and informal science education, and in the scientific field.

TABLE OF CONTENTS

ABSTRACT

Johnson, C. The Impact of Informal Education on Formal Education in Science: A Symbiotic Relationship (2017)

Classroom science teachers face many obstacles, from standardized exams to including real world concepts in their science units. Informal science educators are looking for ways to expand their mission into school curricula in the form of activities and project-based learning. Incorporating real-world experiences from informal science institutions can supplement and enrich the formal science educator's classroom learning units. The research in question in this Capstone was to address how formal and informal science educators can work together to increase students' participation in science and the environment. I interviewed science professionals about why they pursued a career in science and I interviewed classroom science teachers about their needs, focusing on how to harness support from informal science educators.

CHAPTER ONE

Introduction

The purpose of this Capstone is to research the impact of information science education on formal science education. With the support of informal education, can formal educators improve their students' performance in relation to science education standards, in addition to improving their students' impact on the environment? In this chapter, I will provide personal experiences associated with my formal and informal education and explain how these experiences helped me become more engaged in science and nature, both in school and through extra-curricular activities.

My Relationship to Formal and Informal Education

In posing the question about the value of informal education and how essential it is to the success of formal education, I drew upon personal experiences. As I reflected on my formal education, I soon concluded that my most successful academic activities were often influenced by experiences that fell outside an assigned textbook, particularly in the science field.

As a youth, informal education helped me become more engaged in science, both in school and through extracurricular activities. Many of these informal learning activities took place during my years as a cub scout, when I traveled outside of my hometown in Southeast Australia to explore unfamiliar places. Whether I was in the wetlands, the outback, or the ocean, in each place I developed an even deeper appreciation for animals. These experiences motivated me to protect animal habitats.

As I grew older, because of these pivotal experiences, I was drawn to science as it applies to the world around us. For my undergraduate degree, I concentrated on environmental conservation. As an undergraduate I soon realized that a major part of my efforts in conservation would consist of educating others to conserve and protect our natural resources. First, though, I needed to develop my own knowledge about conservation. So, I set out to conduct research and collect data. I collected qualitative date on how people conserve water and recycle; on their knowledge of stormwater pollution prevention; on how they connected to the outdoors; and on whether they had completed footprint surveys. This data helped me understand environmental stewardship stands generally. I also collected quantitative data from the Blanco River in San Marcos with the Stream Team at Texas State University and then developed qualitative data from those results.

At every turning point in my academic career as an environmentalist, I can point to informal experiences that influenced my choices, whether that meant exploring a new topic or delving deeper into the one at hand, or making critical career and lifestyle choices. In my current role, I create opportunities for formal and informal educators to collaborate on bringing students closer to science and nature. My goal is to create partnerships with formal science educators to support their students' learning and broaden their involvement in science careers, conservation, and enhanced performance on standardized tests.

My Journey

My journey as a scientist began when I was six years old in Melbourne, Australia, and my parents surprised me with a couple of black moor goldfish in a small round bowl. I watched my fish curiously and, over the months, I collected more goldfish from the local pet store. I also collected minnows from local ponds. I was amazed that the minnows would always swim in schools in my fish bowl and wondered if it was to protect themselves from the larger black moor fish. Looking back, I don’t think the black moor fish would have eaten the smaller fish because I always overfed the fish. No wonder they only lived a few months. After a few years, I bought a larger aquarium and collected freshwater tropical fish; they were bright in color compared to my previous fish. I collected blue and golden gourami, swordtails, red tail sharks, tropical snails, danios, cardinal tetras, angelfish, live plants (I am not a fan of plastic plants), and schools of neon tetras.

Fish became my passion. My father would take me to an aquarium about twenty minutes from my house. The owner was well-educated in tropical fish. I could ask him all sorts of questions about where the fish were from, what they ate, if they were compatible with other fish, the typical pH range for the fish, and which plants would provide the best habitats and balance for the fish in my aquarium.

I raised other pets: a pair of mice called Pixy and Dixy, a pair of parakeets (a species of birds), a Burmese cat named Sylvester, and a black lab-boxer mixed dog called Max. All those pets were, to varying degrees, inspirations in my life, but with my aquarium I could practice the scientific method and explore a model environment. As a fish owner, I fell into informal scientific educational experience naturally, without even realizing how much I was learning. In fact, my fish led me to one of my first successes in the classroom.

My Fifth Grade Science Experiment

One of my most memorable scientific studies was a project for my fifth grade science fair. While I enjoyed science, no one had yet encouraged me to pursue the field, maybe because my test scores did not indicate that I would be successful in a career in any science field. However, this time I amazed many people, including myself, with the testable question I came up with for the fair: "How do pH and temperature affect the health of my fish?" I chose to create an experiment using my aquarium because once I accidentally increased the temperature on the aquarium thermometer and soon after saw the effects on my tropical fish. I was curious about how far I could increase the temperature before I saw noticeable changes in their behavior.

My controlled variables were the size of the aquarium and filter used. My independent variable was the temperature. The dependent variables were the pH and the effect of temperature on the fish in my aquarium. I analyzed the pH and temperature every day for one month and recorded the results in a table. After the experiment, I created a graph to show the changes in pH and temperature. In my experiment, I demonstrated that as temperature increased past a certain degree, the fish began to "faint" and slowly float to the top. When I decreased the temperature, the fish did not react as much as they did when I increased temperature, but they still showed signs of discomfort. In relation to pH, temperature did not play a huge part. While my focus was temperature changes, I observed other environmental factors in the aquarium throughout the experiment. I questioned several factors that might attribute to the behavior of my fish. Were the fish "fainting" because I was changing the water too often? Was it because I added too much of either a basic or an acidic indicator that helped maintain the pH close to seven? The best conclusion I found was that I changed the water too often without saving some of their original water. Manipulating the temperature on the aquarium heater, I also discovered that I was modeling global warming and the effects of climate change on my fish. In my conclusion, I compared these effects on our lives and what could happen to us if temperatures varied globally.

My fifth-grade science teacher was impressed by my experiment and submitted it to the science fair committee. From that day forward, I was motivated to learn and enjoy science, and, whenever I could, apply my knowledge outside of school to what we learned in the classroom.

Fascination with a Kangaroo Encounter

After I had moved to the United States, many of my friends and relatives would jokingly ask me if I had ever been kicked by a kangaroo. The answer is yes, but only once, because I learned my lesson the first time. This interaction took place when my family visited Healesville Sanctuary, which is in the Yarra Ranges National Park. This land supported many animals in a protected and free-roaming area where visitors and animals are closer together. Typically, kangaroos are around people so often they do not mind some human interaction, although they prefer not to be touched. On this day, I saw a joey in its mother’s pouch and I wanted to pet it. Mind you, I was ten years old, so I should have known better, but I was intrigued by being that close to a kangaroo and her joey accustomed to being near humans and I decided to get closer. Maybe it was my proximity or perhaps she could sense my excitability, but the mother reacted quickly. She first pushed me back with her shorter upper limbs and then gave a quick, but not too hard kick to the gut. I fell down and was a little winded, but I learned my lesson. And the experience didn’t deter me from kangaroos. In fact, I wanted to know more about kangaroos and their behavior. Curious, whenever I visited other zoos and sanctuaries, I made a point to investigate kangaroos’ geographic range, how they survive in the wild, and the effects on kangaroos when they interact with humans. This experience inspired me to focus on a future in geography and biology (later changed to geography and geology).

The Great Barrier Reef as my Classroom.

One of my most memorable experiences connecting with nature was a family trip to the Great Barrier Reef. One of my cousins from Texas visited my family in Australia in 1992 and we all flew to Cairns, a coastal town where tourists explore the Great Barrier Reef. On our adventure, we sailed towards Daintree National Park, located on Green Island off the coast of Queensland, Australia. We encountered crocodiles that were definitely not tamed, and I did not attempt to touch them. On this tropical island, we walked under the canopy of large tropical trees, teeming with birds. I was amazed at the diversity of plants and animals on such a small island. Next was our snorkeling tour.

Snorkeling from the boat out towards a reef pocket, I observed through my mask varieties of fish and the seafloor appeared to be thirty meters deep. I was a little overwhelmed at first, but was suddenly distracted by an Oscar, a black fish with big lips and a few teeth. The Oscar was eagerly waiting for tourists to feed it. It came right up to me and, although I did not have food, it let me stroke it as if it were a domestic dog. After this experience, I began to wonder more about reef systems and the different ecosystems from the southeastern coast to the northeastern coast of Australia. I learned that different factors affect the biodiversity of these regions. Experiences such as this helped me build an appreciation for nature and change my behaviors that would affect ecosystems. Through this experience, I gained more knowledge about ocean ecosystems, biodiversity, and environmental factors that would later help me in my formal education.

My Undergraduate Studies – A Leap Forward

As an undergraduate student at Texas State University, I took a variety of courses, such as Water Management, Oceanography, and Field Methods, where the instructors led field trips that related to our studies. Many of these courses, although guided by professors, provided students with an opportunity to look at the natural world from their own perspectives. In Oceanography, we traveled to the Gulf Coast of Texas and collected small samples from the photic and benthic zones. Our class also toured a wetland that brings the river and ocean together. In my Field Methods course, the class was invited to study and measure the effects of inundations over the Comal River spillway where a canyon was formed. We used scientific tools such as Global Positioning Units, Stadia Rods, tape measures to measure and collect data and analyzed it using computer models and previous data collected from the site. Making these observations and participating in hands-on projects helped me develop my understanding of the human impact on our natural world. These junior and senior level undergraduate courses were a turning point in my mastery of environmental management and critical thinking skills. With my degree in hand, I had the tools I needed to advise a community organization and manage a protected area.

In the Real World

I consider myself a hands-on learner, someone who learns best by observing, doing, and then discussing, instead of reading a concept in a book. I spent two years in rural Guatemala as an ecotourism and conservation advisor. As an advisor in Guatemala, I learned how to work with communities that focus on conservation efforts and how to help others appreciate their natural surroundings, including profiting from ecotourism and conservation practices. Along with advising a community organization, I spent time teaching environmental concepts to elementary students to help them appreciate and, one day, change how they conserve natural resources. These students enjoyed taking part in activities related to the water cycle, making observations about nature, recycling, and plants' and animals' basic needs. During this time, I gained valuable insight into the pedagogy of teaching elementary students in their classrooms, which was different than training adults how to manage a protected area.

After a successful experience with informal education in rural Guatemala, I moved to the formal classroom, teaching bilingual elementary science in Texas. In the beginning, I was met with an uphill battle with a drastic change from the field to the structured classroom. There were more obstacles in the formal classroom setting than an informal setting. I had to understand the district's and school's objectives. I had to learn about the state standards and follow a structured lesson plan. I had to make sure that students understood the concepts to pass standardized tests. Coming from mostly informal experiences, I delivered the activities enthusiastically. The biggest challenge for me with formal education was making sure my students were evaluated after each concept to pass a unit test, because this would essentially lead to their success in standardized tests. As I was teaching, I often wished that we were within walking distance of a national park or a local river, so that the students could learn their material firsthand.

From my current perspective as an informal education supervisor, I understand that formal science educators need our technical experience, knowledge, and resources to help engage their students. The purpose of informal science education institutions is to make sure their audiences are engaged in inquiry-based learning and taking action to support their goals. Formal science educators use experiences in addition to their activities and assessments.

My story is not exclusive and limited to my personal experience. In fact, many successful scientists can pinpoint experiences outside the classroom that inspired them in multifaceted ways. What if we used informal science more proactively to help students navigate their formal education? Would we find a bigger interest in science among students? Would students become more successful in the classroom? Are there limitations to what informal education can offer within the classroom? These are all questions I am prompted to ask as I look back on my experiences and to the future, thinking about collaboration between formal and informal education in the science field.

Conclusion

When I reflect on these experiences, I realize that a combination of formal education and personal experience have helped inspire me to develop my passion, critical thinking skills, and inquiry in science and nature. For example, I collected fish independently and then learned even more about them through a classroom assignment.

As an informal educator and advisor, I worked with communities that helped me define my strengths in my environmental field. In my current role, I help teachers, educators, and administrators navigate informal education, particularly as it applies to formal education.

I plan to explore whether informal and formal educators can collaborate so that students increase their scientific knowledge, appreciate nature, and practice conservation in their homes and in their communities. Through surveys, workshops, and research, I will show how formal and informal educators—along with their students—can establish a symbiotic relationship which works to benefit both groups, whether its inside or outside the classroom. In Chapter Two, Literary Review, I will provide examples of how formal and informal educators successfully collaborate. I will also discuss formal educators' needs and the support that informal education can offer.

CHAPTER TWO

Review of the Literature

The Lasting Impact of Informal Education

As I started in my current role as an education supervisor for professional development, I wanted to learn about the type of support classroom teachers would need to help their students become critical thinkers in science and environmental literacy. Can the support of informal educators help formal educators increase students' performance in relation to science education standards and their impact on the environment? Much of student learning comes from the classroom. However, making connections comes from using outside resources from partnerships with informal learning institutions. My opinion inspired me to ask educators in our professional development workshops and randomly as I met with adult guests at the zoo, to share their experiences with formal education and informal education. Their most lasting memories were unanimously with informal lessons. Visitors cited the zoo bringing penguins to a classroom, the Perot Museum bringing their living planetarium to an auditorium, and families enjoying a scavenger hunt in the Heard Natural Science and Wildlife Museum, among others. The professionals who lead these types of activities are informal educators and they have the ability to bring science and the environment to life in ways that just aren't possible in a standard classroom setting. These informal educators help their respective audiences make connections between science in the classroom and science in the outside world and how it might apply to their lives, whether that means providing visions for future careers to bolstering an appreciation for nature.

Educators are becoming more aware of the lasting impact of informal education. As teachers and students progress through studies, their lesson objectives can be enhanced or even achieved with informal educational activities. After experiencing science out of the classroom, students are also often more willing to learn in school and protect their natural world. The following Review of the Literature will explore how collaboration among formal science educators, outdoor learning centers, and informal science institutions will engage students, not just in concepts, but also in those real-world applications that are related to required science standards in the classroom. As a result, teachers will be able to expose their students to even more fields and potentially spark interest in science careers dedicated to nature and problem-based learning.

Informal vs. Formal Education

Informal education and formal education are two distinct entities, each one with strengths and obstacles. Many of the obstacles between these two entities exist because too often they function separately. With collaboration, both types of education can help students form a rich and lasting understanding of science and the environment.

There are many questions one must ask to consider the most effective ways to bring together informal and formal educators, and we might put at the top of that list: Why is it important to pursue these kinds of collaborations? What separates formal and informal education? How do formal and informal educators meet the needs of their audience? How do formal and informal educators collaborate? Why are some school districts skeptical of informal education institutions? Collaboration, communication, and engagement are important factors in successfully supporting student learning in science education. Thus, we also need to consider: How can formal educators move beyond teaching to the test and collaborate with informal science and environmental educators to support their students' learning?

Formal education and informal education can most simply be defined respectively as lessons that take place inside or beyond the classroom. According to *Enhanced Education* (Accessed on April 3, 2016), "Formal education is classroom-based, provided by trained teachers. Informal education happens outside the classroom, in after-school programs, community-based organizations, museums, libraries, or at home." The classroom teacher has the students for a longer period and focuses on reaching educational standards based on state and federal requirements. Informal educators typically have students for a select period and deliver various engaging activities based overall behind an organization or an arm of that organization.

Science teachers in formal education institutions require more support and collaboration with informal educators to help their students to make connections to real world problems in science and the environment. This is key for students, so that they understand the systems and scientific studies behind their classroom learning. Dr. Meitan Zhang, respected professor of mathematics education, technology, and teaching methods at the University of Texas at El Paso, Texas (2015), declared in her research that it is imperative to understand what teachers need for delivering content and changes in state and national science curricula. Adding that most research centered on teacher education concluded that workshop design was not the main issue, but making sure that specific science content and delivery was relevant and demonstrated a pedagogical framework. High school science teachers and university professors must implement science as an inquiry to demonstrate how new science teachers can produce their own questions about the natural world. Kelly Riedlinger (2011) and her team of instructors from the University of Maryland Department of Curriculum and Instruction Science Teaching Center studied how future science teachers can improve their confidence and attitudes towards teaching science in a formal setting with support from informal science education. In order to facilitate this study, animal presentations and speakers in various science fields were assigned to engage student-teachers. The overall aim was to bring a sense of childhood wonder back into the classroom and inspire students to collect plants or touch unusual living things in the environment. They concluded through their investigation that science education reform must include two important aspects: 1) improve science education at the university level, and 2) partnerships with local informal science education institutions such as zoological associations, Audubon centers, museums, and arboretums to expose not only students, but teachers and administrators.

It is possible to create a rich learning experience by inviting informal educators into the formal classroom setting. Authors Ingrid S. Weiland and Valerie L. Akerson in 2013 examined a partnership between a fifth grade teacher and an informal science educator in a classroom. The formal educator delivered pre-tests and post-tests and managed the classroom. The informal educator engaged students in the learning activity with pedagogy from the formal educator. Summarizing the results, the authors deduced that when classroom teachers focus on the cognitive aspects and classroom management and summative assessment, and informal teachers focus on providing an engaging and hands-on activity, the relationship between teacher and informal educator helps increase students’ interest in science education, exposes teachers and students to science careers, and deepens their inquiry and understanding of the environment.

A successful informal-formal educator collaboration should take into consideration the Next Generation Science Standards that support classroom teachers in connecting students to real world science concepts. These standards are designed to meet the needs of students to compete worldwide in opportunities for careers in science; not all states are involved and it is not a federally funded program. M. Weinstein and E. Whitesell (2014) point out that from 2009 to 2018, the market for STEM (Science, Technology, Engineering, and Mathematics) careers will grow by seventeen percent, hence the importance for students to extend their learning outside of the classroom and immerse themselves in real-world problems. Informal science educators have the resources to support science teachers in their classrooms. Formal science educators have the potential to help adjust engaging informal activities so that they meet the Next Generation Science Standards. Thus, a balance is applied where students can become confident in science in the real world and science in formal examinations mandated by state and federal education institutions. Middle school science teachers partnering with informal science educators have a better chance of engaging their students in biology, physics, chemistry, conservation, and engineering through inquiry-based learning in an informal science institution setting, such as zoos, museums, and gardens (Weinstein et al, 2014).

Current Obstacles Associated with Formal Education

When education supervisors work with teachers in the classroom, they have the opportunity to discover specific obstacles teachers face when presenting the state science standards to their students. These obstacles begin on the base level, when teachers are just beginning to learn how to navigate the classroom. Deobrah Roberts-Harris, as an assistant professor of curriculum development at the University of New Mexico, Albuquerque in 2014, observed preservice teachers develop their science teaching skills. She focused on a broad range of preservice teachers, from kinder through eighth grade. She collected their classwork and reviewed its application to science content, and she interviewed student teachers after their course completion. Her goal was to measure how prepared preservice teachers are to deliver science content in the classroom. She also considered what preservice teachers gained from their exposure to mentor teachers. Interestingly, her student-teachers observed that their mentors did not teach enough science content in the classroom. Hence they were not able to observe science implementation in the classroom. After practicing different methods of learning and teaching science as future classroom teachers, Assistant Professor Deobrah Roberts-Harris' student-teachers at the University of New Mexico unanimously claimed that they would teach more science and use progressive techniques, such as blending science and mathematics while implementing pedagogy. They also stated that they would prefer to teach students to apply science as a way of doing experiments instead of going through the steps. They would put more work into discussing the methods used to understand the science concept and showing students how to work in collaborative groups. At the end of this research paper, Assistant Professor Roberts-Harris concluded that preservice teachers need more professional development in science and pedagogy at museums, zoos, and regional science centers before they enter the classroom because they do not experience enough exposure in their student-teaching opportunities to observe science applied as a method of inquiry for students (Roberts-Harris, 2014).

Certainly, the study of formal education is problematic. In some classrooms, science education, as stated above, is simply lacking. However, by taking the step to enter the classroom, one can begin to address what issues are hindering students' progress in science fields. These types of studies can help us not only understand issues with curriculum, but also how that curriculum is implemented. Ann Kindfield and Marcy Singer-Gabella, Masters students from Indiana University, in 2010 investigated the perception of science by university students studying to be K-6 teachers and found that "K-12 and university classrooms are treated as transparent, unproblematic illustrations as the content rather than the complex, nuanced renderings of natural phenomena that are part of the context itself (Kindfield, 2010. p. 58.)" Authors Kindfield and Singer-Gabella (2010) followed two biology and geology university courses that were designed for non-science majors. They wanted to understand the level of scientific inquiry in those classrooms and the constraints under which professors implemented the course material. Progressing through the study, the authors identified that instruction in these courses covered a superficial exposure to biology and earth science but did not teach students to apply science as inquiry-based learning. As a result, Kindfield (2010) provided constructive feedback based on classroom observations, formal interviews, and informal conversations with classroom professors and preservice teachers so that future classroom teachers can present authentic science topics in the classroom. If preservice teachers practice scientific inquiry at the collegiate level, then they will be better prepared to teach these topics in the classroom, and not rely solely on a textbook to guide their presentations or not teach science at all.

Professional development in science content and pedagogy is another area that needs attention, especially from pre-kindergarten to middle school. Joni M. Lakin, professor of Foundation, Leadership and Technology at Auburn University, Alabama, and Carolyn S. Wallace, professor of Elementary and Early Childhood Education at Kennesaw State University, Georgia (2015) investigated the professional development that science teachers need to become successful classroom teachers through inquiry-based learning and using effective lesson plan modeling such as the 5E model (Engage, Explore, Explain, Elaborate, Evaluate). According to their research, inquiry-based learning was first introduced in 1966 by Schwab and Brandwein so that students acquire scientific knowledge through practice and draw their own conclusions based on their findings. Besides effective content implementation, professors Lakin and Wallace concluded that professional development in inquiry-based science methods is an essential skill because many teachers have misconceptions behind science as inquiry and those misconceptions filter down to students in the classroom. In Lakin's and Wallace's research (2015), they stated that "developing pedagogical content knowledge in regard to inquiry-based science teaching would mean that teachers would activate and grow their knowledge bases for using inquiry-based pedagogical methods for a range of science topics that they would normally teach" (Lakin, 2015. p.144.) In this study, teachers were assessed in their ability to deliver authentic science lessons to their students. Results from this research found that teachers need on-going professional development in both science as inquiry and content delivery.

When science is not delivered in an engaging and rigorous manner in elementary and middle classrooms, students entering high school will be reluctant to participate in higher level sciences such as physics, chemistry and biology. Continuing beyond high school, far fewer students pursue science in higher learning institutions as noted by David Treagust, professor of Science and Mathematics at Curtin University, Australia (2015). He inquired about initiatives and challenges in science education in Australia and found that elementary (K-6) and high school (7-12) students' science scores have not improved over the past twenty years compared to other regions in Asia and Oceana. According to Professor Treagust's study, he found that student performance is directly related to the quality of science content and pedagogy delivered by the science teacher. Thus, the Accreditation of Initial Teacher Education Programs in Australia now evaluates preservice and new teachers, checking their mastery of the science content and their delivery in the classroom. Measures to introduce new teachers to the classroom have also changed in Australia. For example, a qualified science teacher must now have an advanced degree in education and a focus on secondary science curriculum in chemistry, biology, and physics. Professor Treagust's research in *Science Teacher Education in Australia* reveals a domino effect in science education: When teachers have not personally experienced quality science education, their ability to deliver content to students is a reflection of their past knowledge and experience.

It is essential for teachers to receive the skills they need to bring a lively, lasting learning experience into the science classroom. A glaring gap in teachers' skills, as the research above demonstrates, lies in having the opportunity to witness science taught well. One way to address this gap may be to bring more informal education into the classroom. Informal education can enrich a class in a school (or liven up a science lesson outside the classroom) and it can offer students a chance to witness real-world application of science.

Expanding Learning with Informal Education

Ambitious formal educators can reach out to informal educators to help create a vibrant and robust learning experience for their students. This connection can also be initiated by teachers' supervisors. School instructional coaches and administrators are more often seeking professional development for science teachers at zoos and other informal education centers in the region. These coaches aim to provide teachers throughout their region with material directly from informal sites. They also help teachers assess when it might be most beneficial to bring their students to the zoo or other informal scientific centers, such as the Audubon centers or museums.

One of the most common questions for teachers is how to engage students as they explore concepts, particularly in the science standard "Organisms and the Environment." In this category, teachers do have literature and online simulation programs, such as *Stemscopes* (an online curriculum aligned science program developed by Rice University, Houston), and yet classroom educators still feel that their students and their teachers need real connections to science and the environment. This need is particularly important at the elementary level, where their exposure to science courses and experience in exploring science concepts in the real world may be limited. Phyllis Katz and J. Randy McGinnis (2012) inquired about the influence of informal science education on pre-service classroom teachers participating in professional development. Teachers participated in various science activities and implemented them with mentored students in an afterschool program. In their research, they discovered that after participating in workshops led by informal educators and by leading their own groups of students in an afterschool program, the pre-service teachers were more knowledgeable and prepared to teach in elementary science classrooms. A program organized by the Perot Museum of Natural History called the Kosmos Energy STEM Teacher Institute provides teachers with a year-long support system that includes professional development, support in the classroom, and exposes pre-service and current teachers to different informal science institutions, such as zoos, botanical gardens, Audubon centers, medical centers, and other institutions. These organizations support teachers with science content, pedagogy, and delivery.

When reaching out to formal education institutions, science coaches, and administrators, two of the most important factors informal educators must address are how informal education institutions can connect with and improve classroom learning and what opportunities exist for cooperative learning in a different setting other than their classroom. Education development expert Niels Bonderup Dohn (2013), Associate Professor of Danish School of Education, stated in his research that when students are given an opportunity to socialize in an interesting learning environment, such as a zoo, their cognitive reasoning for learning the objectives increases. This form of hands-on learning helps students explore the topic in an informal setting. They are learning for enjoyment, which then motivates them to learn the classroom material. Professor Dohn's (2013) study also demonstrates that an informal institution serves a student best when the presenter, such as a keeper at a zoo, understands the student learning objectives. The student-keeper relationship can thus serve the student better, focusing on topics that are relevant to the student's learning objectives.

By working together, informal and formal educators can establish exciting, robust learning environments and still meet the benchmarks required by educational standards and their current curriculum. K. Johnson (2015), hypothesizes that museum visits serve as supplemental learning tools to school curriculum. She also found that many museums will align with the state curriculum guidelines by providing preliminary and posterior activities to enhance the learning experience. Many teachers do not use local resources as support because they feel more preparation is involved or are concerned that they will have to raise funds for their visit. Another concern is that a field trip may interfere with the amount of time teachers are allotted to cover student learning objectives. And yet Johnson affirms that museums in an informal setting allow students to observe, learn, and inquire about artifacts, creating a robust learning environment for cross-curricular course objectives that not only help students learn about science, but also sequence stories of people and events. For teachers and administrators to overcome their reluctance to visit museums, they should be cognizant of their students' visit to the museum, consider what their students could potentially learn, and explore how their experience could enhance their understanding of concepts they are grappling with in the classroom.

Informal science education can occur in museums, zoos, science centers, and even in the playground, per Linda Ramsey-Gassert in her study on *Learning Science Beyond the Classroom* (1997), where students become excited, involved, and actively engaged in the learning experience. One advantage that science teachers should realize is that museums, zoos, and science centers are hands-on and offer a real-world approach not only to science and environmental literacy, but they also help students perform well on mandatory tests. Most informal educators aspire to entertain visitors to go beyond their zoo or science center exploration; students and teachers have the space and the time to explore at their level of understanding. The experiences that they encounter nurture an opportunity to make connections to the real world. Linda Ramsey-Gassert's (1997) research revealed that although there was no difference between playing and learning for early learning students; teachers noticed that students were actually learning.

The popularity of informal scientific sites is quite staggering. In *Understanding and Engagement in Places of Science Experience*, by Stephen Schwan, Alejandro Grajal, and Doris Lewalter (2014), "170 million people visit zoos, aquariums annually, which is more than the combined attendance of football, hockey, and basketball games combined . . ." and "over 700 million annually, in which most visitors worldwide consist of three or four adults and one or two children on average" (Lewalter, 2014. p.71). Schwan in his research writes that zoos, aquariums, science centers, and science museums to "include overlapping contexts: physical, sociocultural, and personal that contribute to the learning outcomes" (2014). The physical context is the exhibit design that invites guests to experience the activity or premise of the exhibit. The sociocultural context is how the activity facilitates a learning experience with in the group of visitors. The personal context comes from the visitor's prior knowledge, personal interest, and beliefs. In these informal settings, the learning concept is for visitors to have a rewarding and fun experience that curators develop as a learning experience. In the science classroom, student learning not only depends on students' prior knowledge and experience, but also the teacher's knowledge, interest, and willingness to expose students to zoos, aquariums, and science centers. Schwan (2014) stresses that for school groups to bring students to a nature center, their programs have to be authentic, engaging, and relevant to diverse age groups and backgrounds.

One area that does not receive enough attention in science research is secondary biology, possibly because high school teachers may have the expertise necessary to help students understand the science content for testing purposes. However, they should still find ways to weave the real world into their science curriculum. Christoph Randler, Barbara Kummer, and Christian Wilhelm in their 2012 research on *Adolescent Learning in the Zoo: Embedding a Non-Formal Learning Environment to Teach Formal Aspects of Vertebrate Biology* examines the effectiveness of the activities in vertebrae biology, adaptations, and animal behaviors in zoos. The study centers on student learning in an environment outside the formal classroom. Randler, Kummer, and Wilhelm (2012) found that when zoo educators and classroom teachers provide a specific objective, zoos can be effective resources for formal learning. A misconception of zoos and science centers is that many formal educators and administrators see them as fillers or fun field trips. Informal educators will tell you that fun is certainly their objective, but learning is essential too. They also want visitors to understand the philosophy of the center, such as conservation or cultural preservation. This combination of learning and entertainment helps draw visitors, to the extent that they often become stewards of the center and its mission. In Randler's (2012) study on a student unit on vertebrate biology at a zoo, effective implementation of field trip objectives from the formal classroom teacher is communicated to the informal science instructors. The same topic on vertebrate biology is covered by a zoo educator to help students make connections to their classroom learning. Students are better prepared and more engaged because students have clear expectations about their field trip. When students interact with the informal instructors, they are able to connect the classroom learning objectives on vertebrate biology to animals in their respective exhibits. In this case, the formal and informal educators worked together to engage students and evaluate their understanding of vertebrate biology, adaptations and animal behavior in their environment. Among other things, Randler (2012) concluded that when a teacher or a docent led an interactive and self-directed tour through the exhibits at an informal center, the students responded enthusiastically. Independent student-led activities also yielded positive results. These approaches yielded more favorable experiences and higher summative test scores among student groups as compared to groups that did not have these elements in their tours. Randler assessed the reproduction, comprehension, and application of *Bloom's Taxonomy* and asserted that, in this case, the visit to the zoo increased students' retention and comprehension of animal adaptation and behaviors in a biome represented in zoo exhibits. These studies all show that informal education institutions have the potential to support formal educators if they collaborate effectively.

Environmental Education, in the Classroom and Beyond

Environmental education relates to how humans use natural resources and the effects of extracting and using these resources have on our planet. Yodi Sata (2015) associated environmental education with learning about the human effect on our planet, especially related to the socio-economic and quality of natural resource consumption. Sata (2015) introduced his research with the global impact on air pollution, water contamination, rapid extinction of species due to habitat loss and urban sprawl. These are examples of themes that teachers could bring to their classrooms, homes, communities, and regions. Environmental topics are broad enough that they can be integrated into cross-curricular thematic units in science, mathematics, social studies, language arts, art, and music. In environmental education, teachers initiate engaging outdoor activities and collaborative projects that help students and teachers to appreciate the natural world and take care of it. Sata (2015), on behalf of the *World Wildlife Fund*, evaluates environmental education as a resource to be implemented in K-12 curriculum. Implemented by the Taiwanese government, schools are provided with resources and funds to maintain an environmental center with a qualified environmental educator that encourages student groups to participate in various local and relevant environmental themes. According to the U.S. Environmental Protection Agency's National Research Council in *Science for Environmental Protection: The Road Ahead (2012),* some of the most pressing environmental issues we face are a result of environmental challenges mostly caused by humans. Examples of environmental challenges include chemical discharge from factories and from farming practices in our waterways, air pollution, water quality, consumption, energy choices, land use practices, and population growth. To confront these challenges, implementing environmental education provides opportunities for local communities and schools to work together to solve their challenges from water quality to waste management.

In the American Museum of Natural History's Environmental Science: Water Master's course, participants learned about the problems in the Mekong that affect humans that live and depend on the river and species as well. Yodi Sata (2015) mentions several problems that affect water resources from the Mekong such as increasing population density, water consumption, species diversity, human consumption of natural resources, and sustainability. The author adds that through these themes under environmental education, classroom teachers learn about how to incorporate math and science in ways that would generate students' interest.

Environmental education helps students become more aware of their surrounding space including the natural resources and green space in which they learn. Steve Alexander Marable's (2014) research on *Green Schools – The Implementation and Practices of Environmental Education in LEED and USED Green Ribbon Public Schools in Virginia*, examines LEED (Leadership in Energy and Environmental Design) certified facilities designed for schools interested in using energy more efficiently and teaching their students to become better stewards of the environment. Part of the component of Green Schools is to implement state curriculum standards and teach science, mathematics, engineering, and best practices through the sustainable building facilities and gardens. From a conservation standpoint, being part of the green building maintenance can be particularly rewarding for students and teachers; they can make their own positive impact on the environment. From an administrative standpoint, facilitators would want to know if these activities help students master the educational standards. In Marable's study, he observed that teachers find the green facility useful and most of the teachers use it with effective and productive project-based learning, ultimately helping students engage in real world objectives. In this study, Steve Marable (2014) should have mentioned if students' scores increased as a result of engaging them in green building projects. It is possible that there may have been parallel connections to the green projects and tests, but not enough of a significant difference to compare student engagement in these projects and their test results. However, test scores cannot be the only unit we measure when considering a project of this depth and scope. A classroom educator's philosophy on teaching environmental concepts should be separated from educational standards because examinations do not necessarily show how much students know about the environment and sustainability. Also, studies have found that students lose interest in teaching when it is test-driven and not inquiry-driven.

Summary

Based on my research about the current state of formal education, the most compelling challenges facing teachers today are insuring knowledge of content and developing inquiry-based learning. The solution lies in an array of collaborations between informal and formal educators. For example, informal educators could work directly with classroom teachers to supplement their learning objectives. The informal educators would run engaging activities, while the formal educator would manage the classroom and the content as it relates back through pedagogy. Informal educators may also serve as experts in their scientific and environmental fields. Particularly in the elementary schools, many teachers do not have a formalized knowledge of the science content, and this lack of experience can deprive students of authentic inquiry-based engagement in the classroom. Students are less likely to pursue careers in science fields if their classroom experience lacks engaging activities, in part because they have no chance to develop confidence in scientific activity and inquiry. The research in this chapter has demonstrated that students are more engaged and eager to learn about science and the environment when they have the opportunity to visit zoos, aquariums, museums, and science centers that provide interactive science activities. At these locations, they not only see science in action, but they are also able to be part of that action.

In the following chapters, my research will reveal the importance of harnessing informal science education as a way for formal classroom teachers to expose their students to real world science and environmental concepts, and thus influence more students to enter science careers. In Chapter Three, Methods, I will collect data through surveys and interview from a broad array of people who work in non-scientific fields to learn more about their most memorable experiences in formal and informal science. I will expand this survey to colleagues in a zoo environment, focusing on how they became interested in biology, zoology, and other professional science careers. Finally, I will collect data from classroom teachers who participate in my professional development workshops at the zoo. These workshops provide an example of how informal educators' help can create a solid foundation for formal educators. I will use separate surveys for each group to determine how their experiences help them in their current learning assignments and achieve the broader goals they set for their students every year. I will ask these teachers how the workshops impact the way they deliver content and whether they've seen specific differences in the classroom. These surveys will evaluate how students experience science in formal and informal settings; how science professionals were impacted by formal and informal educators; and finally, how today's teachers—the formal educators—utilize informal education when it is available to them.

CHAPTER THREE

Methods

In my research, I used mixed methods, including both open-ended, closed-ended questions and graphical interpretation. I presented my philosophical assumptions in a variety of ways. I used both qualitative and quantitative approaches in my research design. I intended on asking teachers during professional development workshops, but were not scheduled at the time I was approved to conduct my research. I collected data from twenty formal science teachers using Survey Monkey with questions that explore the effectiveness of educator workshops in association with science and conservation at zoos, nature and science centers, Audubons, and arboretums. These workshops developed formal educators' knowledge of science and nature, in addition to considering what kind of support they can receive from informal education institutions.

I originally sent the survey to roughly eighty teachers and ended up collecting a population sample of twenty individuals from the formal science classrooms. Since I collected twenty surveys from formal educators, I also interviewed twenty science professionals that work in a zoo, Audubon center, and science centers. Individuals in the formal science classroom and formal science professionals completed a variety of questions based on their experience in their careers. I consulted my advisors on how to present these results. Since my population sample for the workshop is mostly formal educators, I also present the results as sequential mixed methods to show numerically how a portion of the population reacted a certain way to a survey question.

Additionally, I created questionnaires that asked formal and informal educators whether they felt informal and formal education institutions successfully supported them in their formal education experiences and in their current roles in scientific fields. I also asked science professionals whether they were influenced by formal or informal science education.

My methodology chapter shows evidence of how teachers, colleagues, and professionals in the field of science, have experienced or are working in the field of science and the environment or teaching science in elementary and secondary classroom settings. A survey for formal science teachers and interviews for science professionals provided questions about their most memorable or greatest impact in formal science, informal science, and environmental education. I investigated teachers' experience that participate in professional development for science workshops and analyzed their engagement and comfort level after completing the workshop at the zoo or similar informal education setting. I wanted to understand how a classroom teacher thinks about science, especially the kindergarten through the end of middle school teachers. In each of the surveys, I used the *concurrent triangulation design methods* (Creswell, 2009) that includes a mixed methods approach, specifically descriptive qualitative methods and numeric data collection. This strategy allowed me to observe both qualitative and quantitative approaches and compare the results. In order to show my reasons for using a mixed methods approach, I referred to published authors such as Nasser Mansour's (2007) methods on *Challenges to STS Education: Implications for Science Teacher Education that* he completed through the University of Exeter, United Kingdom and Tanta University, Egypt. My goal in this chapter was to reveal how much informal education has influenced individuals when involved in formal education and environmental education through mixed research methods.

Overview

Followed by the introduction that provides a synopsis of my methods chapter, I first defined the methods approach used to present my data sets. In my mixed methods approach I demonstrated a triangulation of responses related to formal and informal education. Under the heading of my mixed methods approach, I described how I used qualitative and quantitative methods. I applied qualitative methods in the form of a description of individuals' experience in formal and informal education. In addition to the description, I applied the quantitative methods to show a numerical representation of their expressed interest or participation in science and the environment. Next, I provided evidence of previously applied mixed research methods. Nassar Mansour's research presented us with a form of triangulation for accurate qualitative and quantitative results. The proximate section describes the individuals involved in my study at the time of completing the survey. Two parallel groups of individuals have in part been influenced by informal and formal science education. Succeeding my description of individuals, I defined how I protected the answers to survey questions completed by participating individuals. Next, I described the setting where I collected individuals' responses to survey questions. These responses originated from professional development workshops at the zoo, Audubon, nature centers, science centers, and by formal science educators.

Mixed Methods

In John Creswell's *Research Design: Qualitative, Quantitative, and Mixed Methods Approaches (2009),* he explains that the mixed methods approach is a method of combining qualitative and quantitative methods to "broaden understanding by incorporating both qualitative and quantitative research . . . to better understand, explain, or build on the results from the other approach” (Creswell, 2009. p.204-205). My methods objective shows my results in a descriptive form and in a graphic form; this helped me close the gaps or dilute misconceptions that may be evident in one of the methods. Planning mixed methods procedures entailed developing a variety of questions or options for individuals participating in my surveys to describe or numerate responses that emphasized how informal education has impacted formal education institutions. The three different methods of collecting data from my two sample groups were surveys with five scaled questions, two multiple choice questions, and two open-ended responses. After collecting the data, I calculated how many individuals responded a certain way to the scaled and multiple choice questions and created graphical representation of their responses.

Qualitative Methods Approach

In the qualitative methods approach, I collected data responses from formal elementary to middle school teachers that develop and deliver science content in the classroom. I asked educators through Survey Monkey to describe how they felt about applying the science material acquired through professional development workshops in their classrooms. I also asked participants to describe how they felt about the zoo as a promoter of conservation and animal care, which relates to my individuals’ perception of institutions that have an environmental and conservation message as well as a place to acquire science content such as in Category Four, Organisms and the Environment of the *Texas Essential Assessment Knowledge and Skills* science standards for the state of Texas. Data expressed by qualitative methods explicitly connects qualitative and quantitative methods when I provide a mixture of open-ended questions, scaled questions, and close-ended questions in my surveys.

Quantitative Methods Approach

After collecting surveys from my individuals, I quantified their responses to show how many participants felt that they have more confidence and ability in teaching science before and after the workshop or activity. I also quantified how many educators identified the objectives and methods of implementing environmental and science content in their classrooms. Some individuals in this group may have a science background and others may not. My goal was to find out if individuals' path to a science career was a result of a scientific experience at the elementary or secondary school level. Transforming survey responses into numerical data sets using bar charts, supported the qualitative data descriptions that represented survey responses. Successfully creating surveys for each of my groups of individuals that include a collection of qualitative and quantitative methods approach refers to the *concurrent triangulation strategy* (Creswell, 2009). As the term concurrent suggests, the data can be interpreted from a qualitative descriptive method to a quantitative method or from a numerical interpretation of the data to a descriptive expression of my individuals' responses invariably.

Research Framework Supported by Sources

Nasser Mansour of the University of Exeter, United Kingdom, and Tanta University of Egypt (2007) investigated the constraints of teachers using science technology in the classroom, their experience in using science technology, and the influence of constraints in science teachers' performance to teach science technology. Mansour's ultimate question was to understand the relationship among the constraints.

Mansour used methodological and researcher-participant methods, and he triangulated his data by including surveys, interviews, and observations, to make sure his data reduced errors in his compilation that "cross-checked the meaning of data obtained from various methods with participants" (Mansour, 2007. p. 484).

In Nasser Mansour's *Challenges to STS Education: Implications for Science Teacher Education (2007),* he collected data through surveys using a combination of qualitative descriptive data and quantified data that ranked responses. The interviews gave participants the opportunity to express their experiences with science technology in open-ended questions. In the quantitative data, where Mansour provided questions for participants to rank their responses, he used *Cronbach's coefficient alpha theory* to reduce bias or error in analyzing the responses. According to the *University of California Los Angeles (UCLA)'s Institute for Digital Research* and *Education,* "Cronbach's alpha is a measure of internal consistency, that is, how closely related a set of items are as a group . . . as a measure of scale reliability" (IDRE, 2016). After collecting survey responses, Mansour presented the data in a table showing the frequency of individuals interviewed along with the percentage of individuals that felt pressured to teach science technology in the classroom and the availability of resources for teachers. Nasser Mansour (2007) described examples of his individuals' responses in qualitative descriptive methods. Descriptions of how teachers felt about trying to prepare their students to compete in science technology in the classroom was noted and the lack of time available to prepare such rigorous lessons to students (p.486-487).

Participants

I chose two different groups for my investigation that relate to science education in formal and informal settings and their experience in environmental education. In both groups, I found out what sparked their interest in science and environmental education:

- Group one: co-workers, such as instructors, zoo keepers, supervisors, and upper level managers such as directors and curators at the zoo, and other informal institutions.
- Group two: formal educators that participate in my professional development workshops at the zoo and in their classrooms. Collecting data from formal educators will help me understand if relationships among formal and informal educators support educators and their students in formal science education.

After collecting data from the two groups, I analyzed the responses that refer to experiences in formal and informal science and environmental education. Additionally, I collected data about the support that formal science teachers receive and need in their respective learning environments. After analyzing the data, I synthesized responses using descriptive methods and quantitative methods to demonstrate the factors that push and pull individuals towards science education.

Approaching my individuals to participate in my research study will be with clarity and discretion to protect their responses to questions, not only out of respect to agree to share their responses with me, but to also receive authentic responses. Along with asking for their permission before the activity, I provided them with a survey and a statement or question that gives me permission to use their responses; I used the term individuals, formal science teacher, or science professional in reference to each person in my survey.

In addition to the individuals that require consent to use their responses in my research, I conferred with my primary, secondary advisors, and peer reviewer. My primary advisor guided me in shaping the format of my capstone research. My secondary advisor advised me on how to approach my individuals along with helping me develop my survey questions and permission to distribute surveys at the zoo. My peer reviewer is an author, editor, and New York University graduate who helped me with grammar, spelling, punctuation, and flow of my research chapters.

Study Location

Most of the time, my professional science individuals were in the zoo or other science learning centers, and informal science learning environments. The investigation for one group drew attention to aspects of formal and/or informal education that helped my co-workers choose a career in informal education or a field in science such as zoology, biology, nutrition, or environmental education, for example. The other group of individuals responded to questions pertaining to the knowledge and experience they acquired in professional development workshops and how effective they were to apply to their formal classroom teaching. In each of the groups, individuals answered questions about their general experience in science education and environmental education associated to formal and informal education. In this survey I wanted to know how much their most engaging memories of science education and environmental activities from elementary school up to 2016 influenced them to pursue science careers or have some part in environmental education or conservation. I discovered that their formal and informal science education helped them engage in science and environmental education.

Conclusion

Implementing a concurrent triangulation research method, I extrapolated data from individuals' surveys to understand their relationship with informal and formal science education, and their relationship with respect to the environment. Questions within the two surveys informed me that individuals have/have not been influenced by formal/informal science education. Individuals such as teachers explained that their experience in teaching science in the classroom was influenced (or not) by an informal science experience or higher level science courses. Based on the research papers in Chapter Two, I have realized that in most cases, primary or elementary teachers will have little exposure to science education, but not necessarily related to their knowledge of the environment.

The population from survey samples consist of two different groups. The first group consist of science teachers from preschool through high school that work in a formal classroom setting; they also participated in professional development through nature centers, zoos, arboretums, and Audubon centers. The second group consisted of science professionals working in the field that promote science from a zoo setting to a nature center. I gathered my results in graphic and descriptive representations such as bar graphs and collective thoughts on formal and informal science education. In Chapter four, I gathered my data for analysis, and in Chapter Five, results section, I synthesized the data and interpreted my surveys related to my topic and provide resources for formal and informal science educators to either collaborate or show that formal science educators do not need further support.

CHAPTER FOUR

Results

This chapter shows individuals' responses to survey questions posed to them about their experiences with formal and informal science education. Separating the formal science education participants' responses and science professionals' response including supervisors, who may not have originally completed an undergraduate degree in biology, chemistry, or physics will reveal how a majority of science professionals chose their careers and the most pressing needs of formal science educators.

The first survey was designed for formal science classroom educators and the second survey for science professionals. I reached out to sixty formal science educators who have participated in professional development at an Audubon center, arboretum, zoo, or nature center. From that pool, fifteen PreK to 12th grade educators responded to ten survey questions about their experience with science and the environment, both as a student and as a teacher. A portion of the ten questions also covered what kinds of support teachers need to make sure their students are knowledgeable and confident as they enter science fields in higher learning and in professional careers. The compilation of data will also show whether formal science educators require more support from informal science institutions to supplement student-learning objectives.

Formal Science Classroom Teachers Tell Their Story

Preschool to high school science teachers provide a social and collaborative learning environment for their students. These teachers help students understand complex problems and allow time to work in groups, pairs, individually, or class. Today, teachers have an uphill battle with standardized testing, ongoing changes in pedagogy and methods in presenting content in the classroom. However, teachers continue to train their students to become future leaders in the community.

The first question posed to formal science educators is if they are more prepared to teach science after participating in a professional development workshop in science with a scale of ‘not at all true,’ ‘somewhat true,’ ‘true,’ or ‘very true.’ Seven out of fifteen science educators responded, ‘very true,’ four individuals answered ‘true,’ and five individuals answered, ‘somewhat true’. In the graph below, the data shows that most science teachers benefited from participating in a professional development workshop.

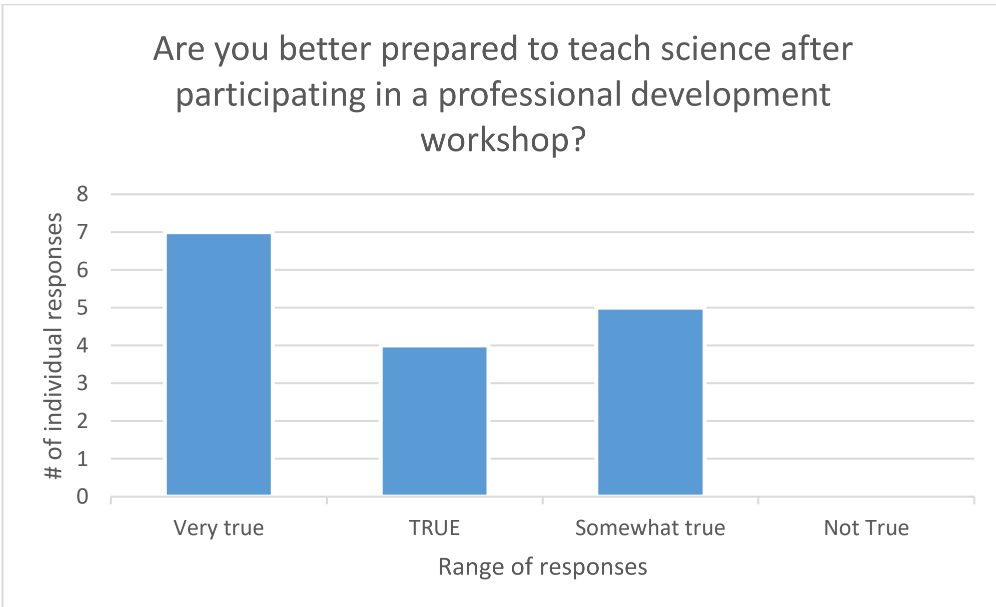

Figure 1: Question 1.

Individuals chose in favor of their professional development workshops for two reasons: 1) They learned new strategies and activities to use in their classrooms; and 2) They gained more confidence after better understanding the science content. Professional development workshops include a variety of topics in biology, physics, chemistry, environmental science, and earth science. Typically, science education institutions are current on most pressing or most challenging standards teachers face in the classroom.

The second question asked whether formal science educators learned new science concepts they could implement in their classrooms. Four individuals responded, ‘very true,’ seven responded ‘true,’ three responded ‘true,’ and one responded ‘not at all true.’ As seen in the graph below, a majority (responses ‘true’ and ‘very true’) stated that they acquired new science concepts that could be implemented in the classroom.

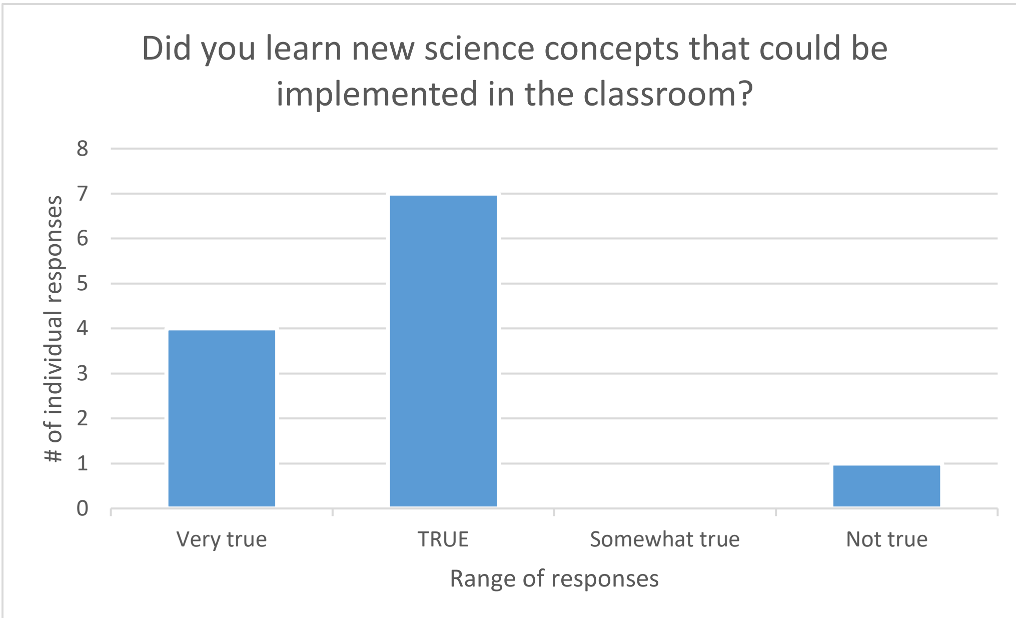

Figure 2: Question 2.

Teachers who participate in professional development workshops reflect on the activities or objectives presented and differentiate or scaffold the learning experience for themselves and for their students. For instance, if the activity presented is on structure and function of mammals, birds, and reptiles, elementary teachers will focus on body parts, behaviors, and body coverings. Middle to high school teachers will use the taxonomic classification to compare mammals and birds from an evolutionary perspective based on their environmental conditions. Many informal science institutions understand that professional development workshops must have a variety of activities that include problem-based learning, science content, and a combination of subjects, such as math, science and reading. These workshops help teachers prepare activities with real world examples, improve their content knowledge, and help them reflect on how to encourage their students to make connections to their classroom learning objectives.

Question three in the survey for formal science educators asked if they are generally prepared to teach students science content, so that students can perform well on standardized tests. Four out of fifteen individuals answered, ‘very true’; seven responded ‘true’; three responded ‘somewhat true’; and one responded ‘not at all true’.

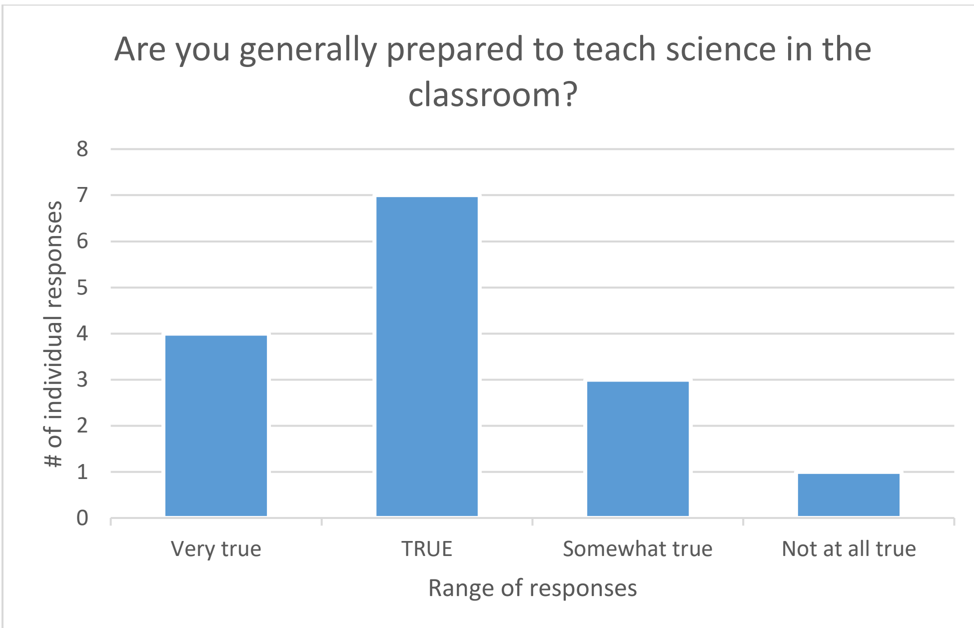

Figure 3: Question 3.

Several factors led to classroom teachers’ responses, which varied, about being prepared to teach science in the classroom. The fact that four of the teachers stated that they are only somewhat to not at all prepared to teach science alludes to the general education certification that teachers are required to obtain to teach. Since this certification covers all subjects and not science extensively or exclusively, teachers’ strengths or interests may be in other subjects, such as math or language arts. The eleven individuals who felt prepared to teach science were also more interested in the subject, based on their experience in the field, in scientific laboratories, and the environment in which they lived or spent most of their time. Based on the previous responses to the three previous questions, teachers are mostly prepared, have a better understanding of the content and how to apply them to the classroom. This experience increases teachers' confidence and excitement necessary to teach science well, providing students with more authentic and engaging experiences in their classrooms. To be a prepared science teacher, there are two components to cover: understanding the science concepts and effectively presenting these concepts to students through various pedagogical strategies. For example, let's consider students who participate in experiments using material provided to them in the classroom. In the process, students must learn how these experiments connect to real-world learning objectives. Apart from having fun, it's important for students to make connections, for example, learning why the morphology of birds' wings matters beyond the classroom or the textbook.

Question four in the survey asked individuals if they have necessary resources to teach students science at their grade level. Four individuals answered, 'very true'; nine responded 'true'; two responded 'somewhat true'. Since most individuals responded that they had the resources, we see that this factor does not adversely affect their ability to teach science in the classroom. Considering that individuals in this survey have acquired material and learned new activities for their classrooms through science workshops, it is reasonable to predict that they would have elected mostly 'true – very true' as responses.

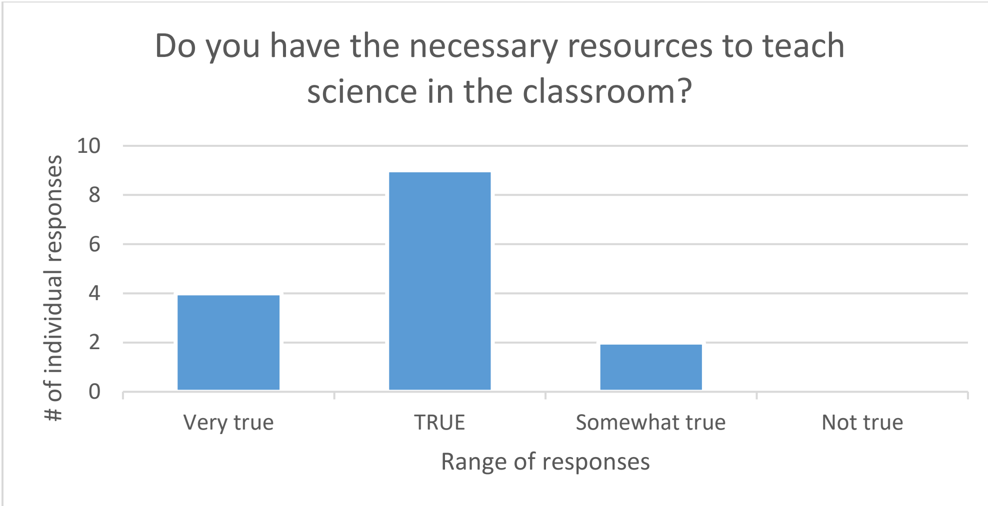

Figure 4: Question 4.

Question five in the survey asked individuals whether science is the most interesting subject to them. The assumption is that if science is the most interesting subject, then teachers will engage more with their students and be more invested in students' science learning. Evidently, most individuals chose in favor of science being the most interesting subject. This infers that even at the elementary level, one would observe science incorporated in their classroom. Six individuals answered, 'very true'; five individuals answered 'true'; and four individuals answered 'somewhat true'.

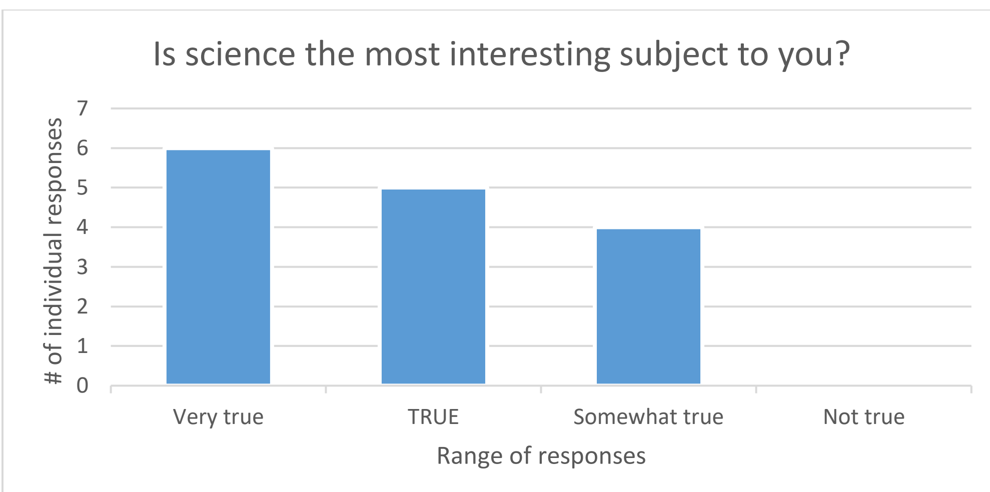

Figure 5: Question 5.

Questions six and seven show these formal science teachers' favorite subjects between kindergarten and sixth grade (elementary) and between seventh and twelfth grade. Choices are Language Arts, Social Studies, Math, Science, and Electives. Of these formal science teachers, for their elementary school years, most chose Science, followed by Language Arts, Social Studies, Electives, and Math. Science also took the lead as favorite subject in secondary school, this time followed by Electives, Language Arts, Math, and then Social Studies.

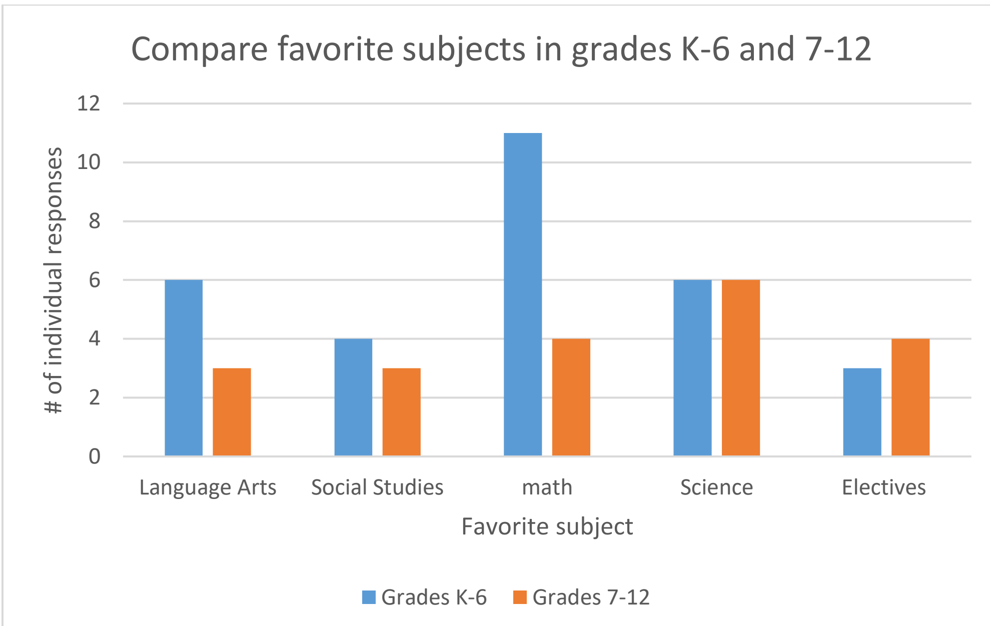

Figure 6: Questions 6 and 7.

Question eight in the survey asked these formal science teachers to identify the first informal science experience that inspired them to engage in science; teachers may bring these experiences to the classroom where applicable. Teachers choose from the following options: zoo, museum, vacation, backyard, school visit, school visit, or nature center. Six out of twenty individuals marked that their first science discovery was in their backyard. Four marked in a zoo. Three marked in a museum. One marked school visit. Three marked on vacation. Two marked other.

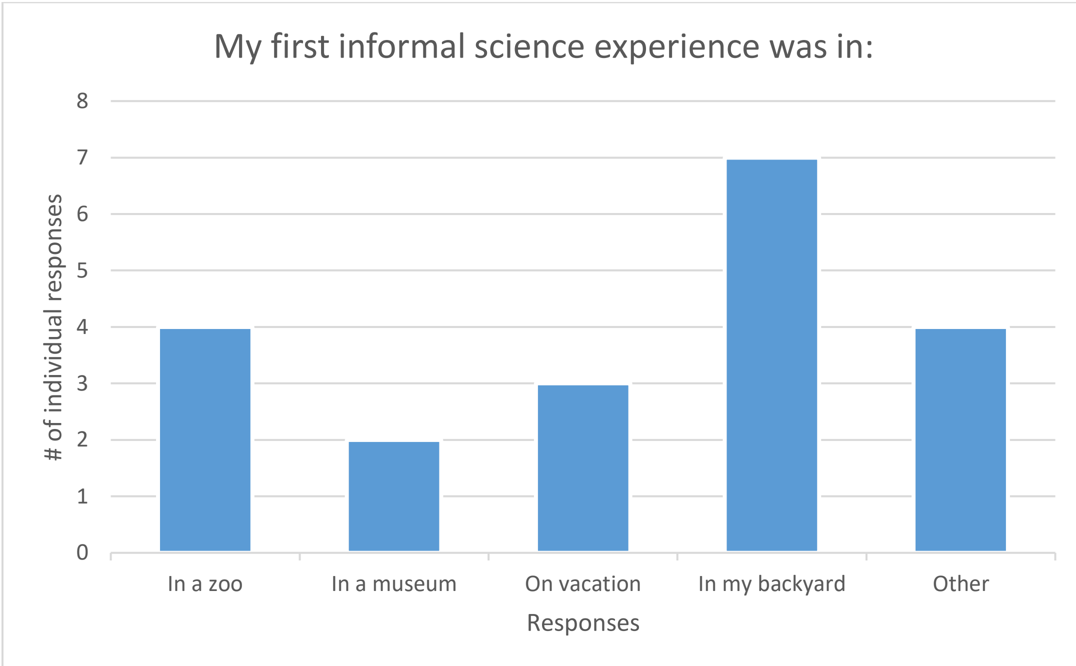

Figure 7: Question 8.

Reasons for Teaching Science

Questions nine and ten ask the individuals for written responses about why they chose to teach science and how informal science centers and formal science institutions could most efficiently support them. Most of the individuals responded that they chose science because it sparked their interest as a child or adolescent and they enjoy teaching science. Other comments referred to choosing science because it is a hands-on and experimental subject. One individual wrote that science is what will create change in the world. Another individual mentioned that prekinder to second grade teachers are typically self-contained educators and teach all subjects, and must include science even through their interests and strengths are in math or language arts. One of the individuals in my study creates the science lesson plans for her grade level because she is the one mostly interested in science. One teacher mentioned that her strength and interests is in teaching math, and in upper elementary grade levels, it is common to teach math and science together.

Most Beneficial Support

The last question in the survey for formal science educators asks what kind of support they should receive from formal and informal science institutions. Training and professional development was the most popular response, especially hands-on lab experiments and real life examples with material teachers may use in the classroom. They suggested that training sessions on how to take advantage of science centers would help too. Another suggestion was to invite students along with teachers to professional development workshops so that teachers see how students respond to the activities. An individual suggested that teachers provide opportunities for students to participate in Citizen Science, such as the Cornell annual bird count or frog club. The goal for this question was to understand what kind of support most science educators need in contrast to what they already receive.

Science Professionals Explain Their Career Choices

The survey questions for science professionals mostly aligned with the survey questions for classroom science educators, except in this case, my goal was to identify reasons for pursuing a science career. Was the decision based on an experience on an informal science experience, such as a field trip to a zoo, Audubon, nature center, or a family vacation? Or was the decision based on an experience in one or more of their science courses between elementary and high school period? For this part of the study, twenty science professionals answered ten questions about their experiences in formal and informal science settings.

Applying the mixed research methods, science professionals answered scaled-questions and descriptive questions with the intention of investigating how more students could pursue careers in science. Factors that shape an individual's career path include experiences in both formal and informal settings. In both settings, the environment in which an individual experienced their first field trip and inspiration from which a classroom science teacher brought science alive in the classroom are equally important for science professionals. These individuals share their thoughts on how they became scientists and advice on how informal and formal educators could work together to increase the number of future science majors.

In the first question, science professionals were asked if they were in a science-related career because of a formal classroom experience. Individuals answered one of the following: 'Not at all true,' 'Somewhat true,' 'True,' and 'Very true.' Five individuals answered 'Not at all true.' Nine answered 'Somewhat true.' Six individuals answered 'True.' The responses, as seen in the following graph, demonstrate that science professionals did not necessarily choose a science career because of their formal science in the classroom. The fact that most individuals answered somewhat true and true, one can infer that the formal classroom science experience had an impact on their decision to pursue a career in science.

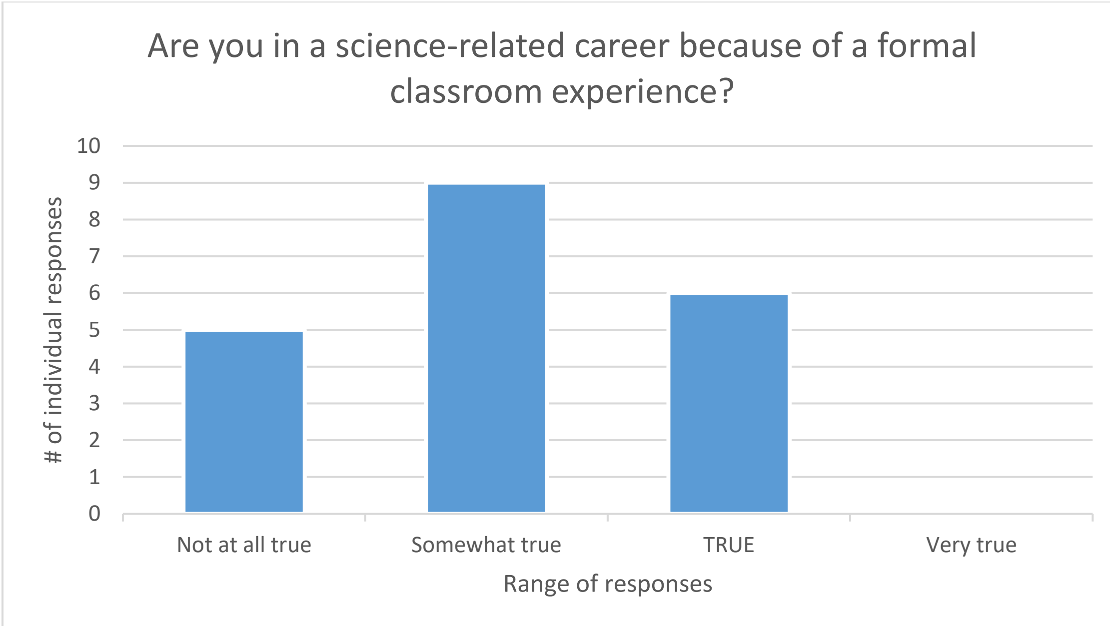

Figure 8: Question 1.

However, science professionals detoured from choosing ‘very true’ as a response towards obtaining a science career, which implies that informal science education experience was also a factor. Most science professionals in this research emphasized that formal science content presented in secondary education and in higher learning institutions helped them apply theoretical concepts to applied science in the field.

The second question asked whether science professionals are in their respective field because of an experience in an informal science setting, such as a zoo, science center, arboretum, etc. Individuals chose from the following: ‘Not at all,’ ‘Somewhat true,’ ‘True,’ and ‘Very true.’ Three individuals answered to ‘Not at all true.’ Three answered ‘Somewhat true.’ Four answered ‘True,’ and eleven answered to ‘Very true.’ While the data show that science professionals were mostly inspired to pursue a science career because of an informal science experience, the formal science classroom teachers helped them understand the science content; thus, preparing more confident in studying science in higher learning institutions.

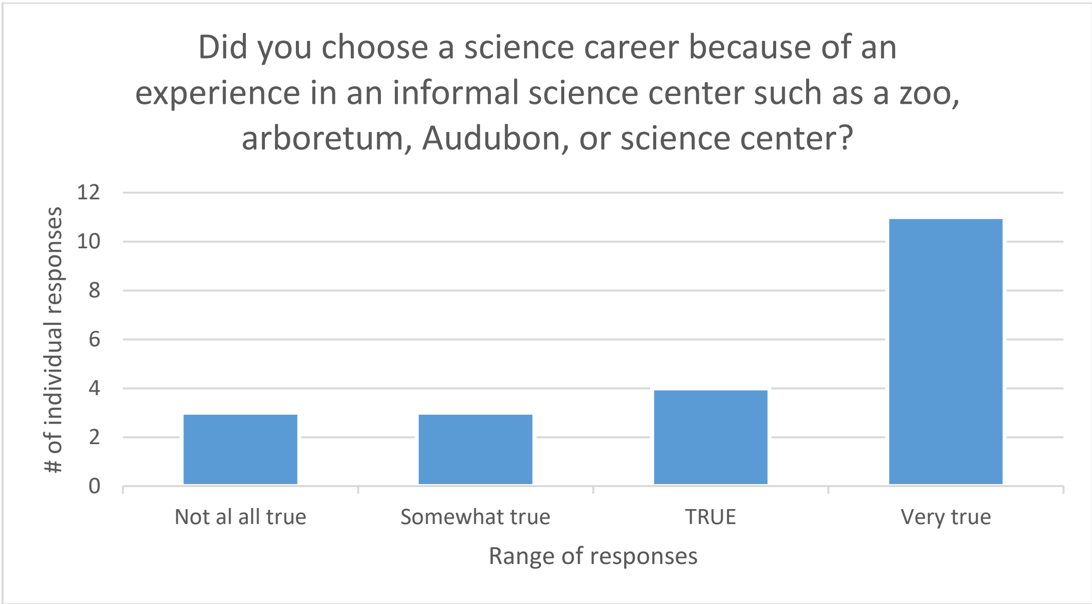

Figure 9: Question 2.

Referring to the responses collected in the previous question, one could have predicted that most science professionals would have chosen 'very true' because they had an opportunity to experience science outside the formal classroom setting. Science teachers exposed these individuals to science in the real world.

Question three asked individuals about whether they were prepared to take science courses, such as biology, chemistry, physics, natural sciences, before taking college level science courses. Three individuals said they were not at all prepared. Two said they were somewhat prepared. Seven individuals said 'true', and eight individuals chose 'very true' to being prepared to take college level science courses.

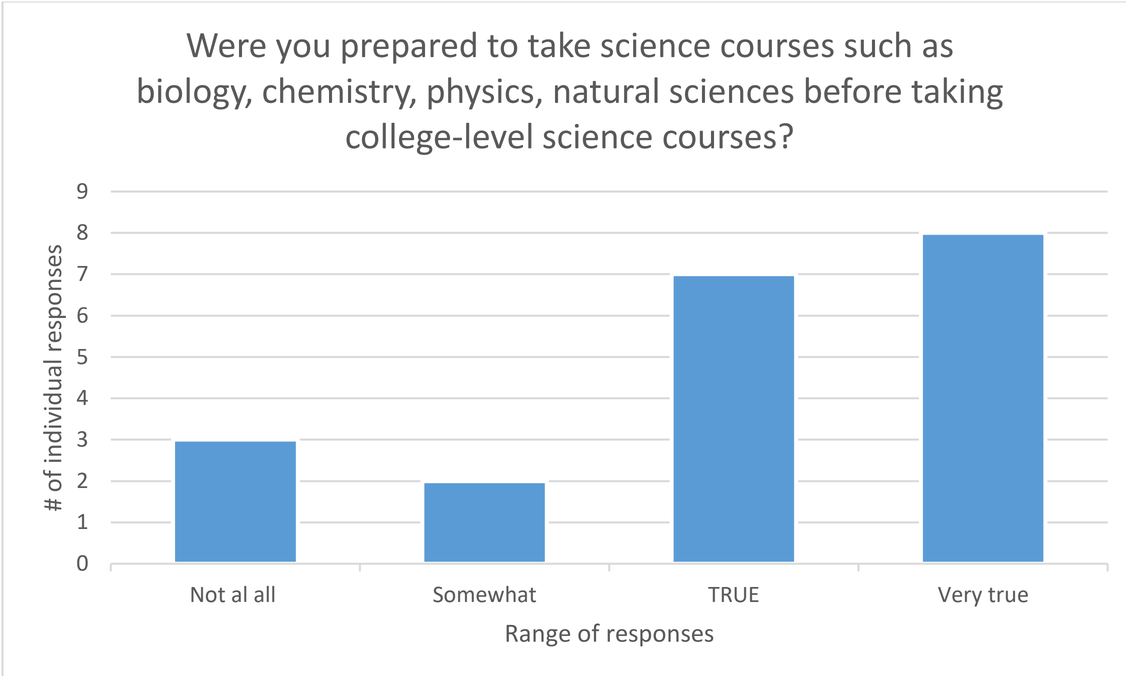

Figure 10: Question 3.

In question three, individuals answered mostly 'true-very true' which also relates to how they responded to the first question about whether formal science education was part of the reason to pursue a science career. Their confidence increases because they are well-informed and prepared in biology, chemistry, physics, and natural sciences. The five individuals that chose 'not at all – somewhat true' may have pursued a science career after several years' experience in an outdoor environment as naturalists or educators. Their acquired knowledge and practical application helped them become more scientifically literate.

In question four, science professionals indicated whether an internship in a science field was helpful in learning the science content. Two individuals responded to 'not at all.' Three responded to 'somewhat true.' Seven responded to 'true'. Nine individuals answered, 'very true.'

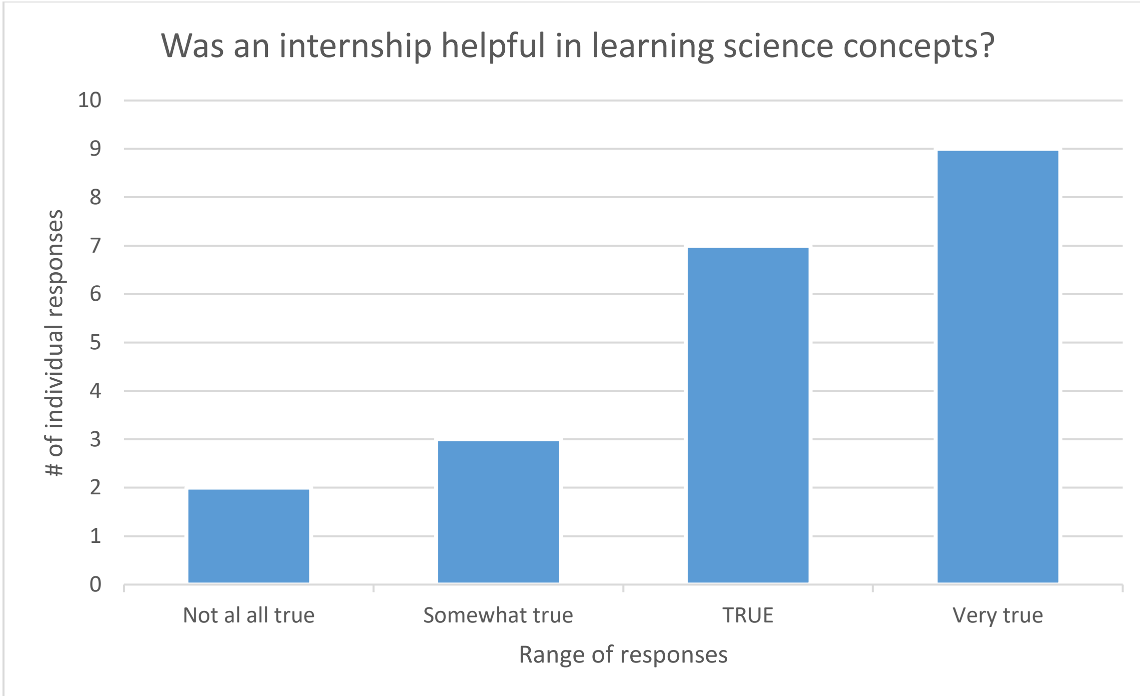

Figure 11: Question 4.

In addition to learning the science content, participating in an internship program provided hands-on experience for future science professionals. If individuals' experience in the formal classroom setting helped them land an internship in the scientific field and the institution in which they worked provided them with the opportunity to learn and grow should help mold their specialization in the scientific field as individuals choose their upper-level science courses. Thus far, science professionals have reflected on their experience in the formal science classroom, application in a field trip setting, and an internship leading up to their pursuit in a professional science field.

In question five, science professionals were asked if a science course at the college level was most helpful in learning the science content. Two answered 'not at all.' Six answered 'somewhat true,' eight answered 'true,' and four answered 'very true.'

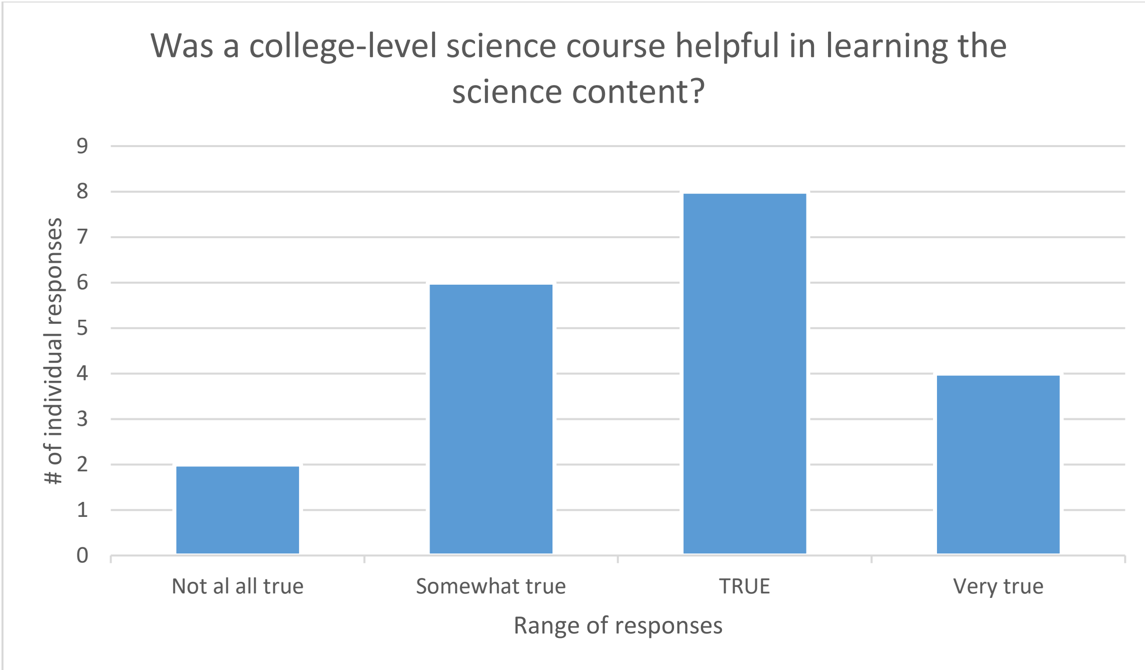

Figure 12: Question 5.

. As individuals solidify their content knowledge in upper college-level science courses, they are better prepared and more confident in pursuing science careers. In a zoo setting, individuals that majored in biology or zoology for example, studied animal behavior, animal physiology and anatomy, and animal nutrition. Along with their upper-level courses and internship, individuals were prepared to work with a team of behavioral biologists, animal presenters, and animal care-takers.

A pattern in the next two questions (six and seven) will show that science professionals were more likely to choose a science-related career because of their interest in science. Twelve out of twenty individuals favored science out of other courses in elementary school. In grade levels 6-12, fifteen out of twenty individuals favored science over other courses taken in school.

Comparing data on favorite subjects between formal science teachers and science professionals, science professionals were passionate about science at an early stage and their interest only grew as they progressed through elementary, secondary, and college-level science courses. While other subjects are important in understanding science, including math and language arts, clearly, science professionals were more engaged in science as their teachers and circle of influence (friends, family, informal science centers) provided many opportunities to explore scientific concepts in and out of the classroom.

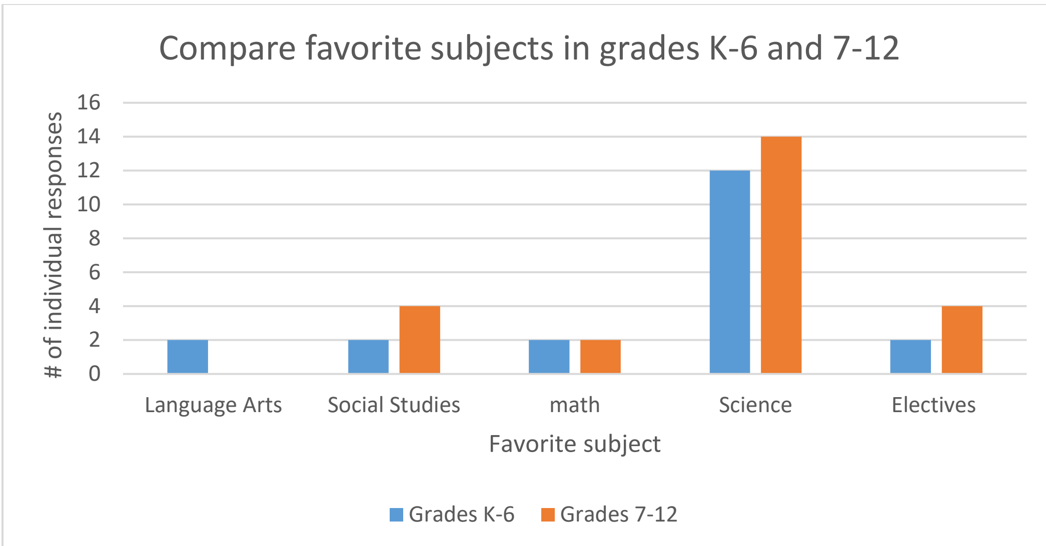

Figure 13: Questions 6 and 7.

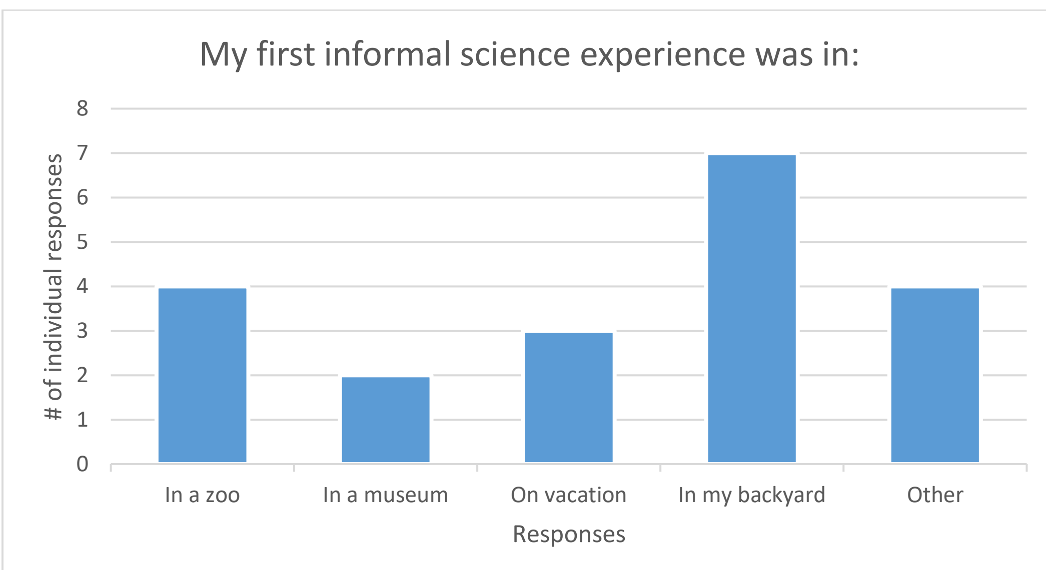

Figure 14: Question 8.

Question number eight asked science professionals where they experienced their first informal science activity, choosing from zoos, museums, vacation, backyard, visitor to their school, or science center. Four out of twenty chose zoos. Two chose museums. Three chose while they were on vacation. Seven chose in their backyard. One chose from a visit to their school, one said from an aquarium visit, and four individuals added 'other'.

Reasons for choosing science and advice

Concluding the interview with questions nine and ten, science professionals described why they chose a science career and what advice they'd give to help lead students to pursue a career in science. Eight out of twenty individuals replied that their primary reason for choosing a science career was their passion for the outdoors, exploring natural areas or even their own backyard. Ten out of twenty replied that they have always been interested in science topics because of their interest and influence by family members or a previous science teacher, or a volunteer opportunity. Other individuals noted they grew up on a farm, loves animals, and want to teach the importance of conservation.

For students to pursue a science career, a majority of the twenty individuals advised that outdoor activities, hands-on experiences, summer camps in science, and field experiments must be included in the learning environment. Real experience in a variety of activities such as bird watching using ethograms to analyze a flamingo's behavior in a zoo habitat or in nature, touching a tarantula, and exploring in nature with guidance on how to ask questions about observations and the scientific method. One individual also commented that educators should encourage students by exposing all students with different academic backgrounds to science. Students can have different interests in the broad range of science topics and should have the opportunity to explore fields in chemistry, physics, biology, and conservation, not only in the classroom, but also in a field trip or outdoor setting for exposure to real world application.

Patterns within Ch. 2: Review of the Literature

In agreement with the responses from formal classroom teachers becoming better prepared and more confident in teaching science in their classrooms, one can refer to Meiten Zhang's 2015 research on professional development for classroom science teachers. When informal science institutions understand the needs of formal science teachers, they understand how to implement new concepts and activities to their students. In addition, formal science teachers and science professionals commented that teachers should be exposed to real world science concepts. This supports Kelly Riedlinger's 2011 study on how to improve confidence and attitudes towards teaching and learning science.

The symbiotic relationship referred to throughout this research between formal and informal science educators is important to support both the informal science institution's mission and support the needs of teachers and students. As noted in Ingrid Weiland's 2013 research, students and teachers may benefit from the collaboration between the two education institutions, thus providing authentic learning opportunities. Science professionals described that they were influenced by both formal classroom science classes and informal science field trips and outdoor activities.

When informal science institutions provide authentic, engaging, and relevant experiences to school groups and teachers, their informal science learning enriches their understanding of science, the natural world, and classroom science content. According to science teachers' responses to advice for science education institutions, students and teachers become better stewards of the environment and science, which supports Diros Lewalter's 2014 research on the effectiveness of zoos, nature centers, and aquariums on visitors of all ages.

CHAPTER FIVE

Conclusion

What I Have learned

While it is important to have standards for education in the United States, classroom teachers are paradoxically faced with many pressures and obstacles associated with established standards that prevent them from improving and enriching their students' learning experience. Classroom teachers face great pressure from local, district, and state administrators to make sure that their students' performances are exemplary on standardized tests. Formal educators are constantly searching for current resources to help them teach science content in their elementary and middle school science classrooms. Based on personal experience in formal education and feedback from several science and environmental teachers, it is clear that the objective in school districts is for students to perfect standards in mathematics and language arts, but science and environmental studies are often only recognized as electives. This hierarchy originates from state and federal mandates to reach certain scores in content areas. To meet the state's standardized testing scores and include scientific literature, informal science institutions must be prepared to cover mathematics, language arts, and science in their school programs and educator professional development, along with a working relationship with formal science educators.

My Research and the Literature Review

Based on the interview responses from science professionals, their motivation to pursue a career in the biological field was a field experience in the natural world or an internship in a scientific field. Holding a spider in one's hand for the first time made one of the individuals inquire more about spiders, and as a result pursued a career in zoology. Other individuals enjoyed camping or exploring in nature and discovered they must share their experiences with others to enjoy future experiences in nature. Many field experiences in nature centers, zoos, aquariums, and Audubon centers provide these rich experiences for teachers and students and help make real world connections to the classroom standards and curricula. This symbiotic relationship between formal science teachers and informal science educators potentially result in a lasting impact on students and their future in science and the environment. Providing hands-on experiences and supporting classroom teachers contributes to the informal institution's mission and increase students' interest in science. Referring to Dr. Zhang (2015) and Riedlinger (2013), both found in their research that future science teachers increase their confidence and provide richer scientific content if they have better training in the science content and relate to informal science educators; they can bring a sense of wonder back to the classroom based on their own sense of curiosity in the natural world.

According to Weinstein and Whitesell's research in 2014, between 2009 and 2018, the market for STEM (Science, Technology, Engineering, and Math) careers will increase by seventeen percent, which means that it is critical for formal and informal science educators to build relationships and expose their students to field trips, internships, camps, and activities in STEM. Not only will these real-world experiences in STEM increase their students' access to a variety of potential careers, they will supplement with examples to scientific content presented in the classroom, as Kindfield and Singer-Cabella (2010) concluded in their research. From both formal classroom educators' surveys and interviews from science professionals, most suggested that students will become more scientifically literate and pursue careers in science after they are exposed to science careers in the field. Both also mentioned that classroom teachers and informal science educators must understand each other's mission or objectives and incorporate experiences that include outdoor activities in natural areas. After a connection to nature, students are more likely make more informed decisions to protect our natural resources for future generations.

For elementary teachers from Kindergarten to fifth grade, science may not be their strongest subject (as noted in my survey for formal science teachers), and instead their strengths lay in mathematics or language arts. Many teachers avoid scientific rigor because they are not comfortable with the content. Individuals from the surveys who are comfortable with science at the elementary level are usually the ones creating lesson plans and leading professional development sessions with other science teachers on their campuses.

Implications and Limitations of my Study and Findings

As an informal science educator, I wanted to investigate the needs of K-12 classroom science teachers to help me understand which grade level teachers need professional development in science. I struggled to connect with classroom science teachers and coordinators. After learning more about teachers' needs, instead of presenting what I assume I should deliver, more educators were participating in my professional development sessions, especially Early Childhood educators (Pre-kinder – Second grade). My studies revealed that, for formal classroom science subjects at the elementary grade levels, most teachers hired to teach in districts throughout Texas' schools have a stronger background in either language arts or mathematics. However, blended classroom teachers are still held accountable for their students' progress in science. Even in weekly professional development sessions for teachers at their schools, elementary teachers are not provided much coaching in science; they typically must participate in math or language arts teaching sessions. Based on my survey results, elementary teachers must be able to teach their students science, especially in K-2 grade levels where teachers must also plan for language arts, mathematics, and science.

In my hypothesis, I stated that when formal science teachers and informal science educators work together, students will improve their scientific literacy and care more about protecting our natural world. While I collected data from science professionals about how they pursued science careers and what kind of support formal science teachers need to support their students, I have not found test results in the literature or on the Texas Education Agency's website. I can, however, state that based on teachers' needs, my hypothesis implies that a symbiotic relationship is the most effective method of achieving the greatest results in the classroom and in science centers.

In the appropriate circumstances with a data pool of one hundred individuals, I would have been able to more broadly analyze teachers' current experience in science education.

Recommendations to Future Research Projects

I have found through my Capstone investigation and my professional development workshops that most teachers, after being exposed to an engaging experience, such as an animal encounter or activities they can use in their classrooms, are more enthusiastic to learn more about science and are more confident in adding science content in their classrooms. Teachers should be exposed to a variety of informal science institutions such as nature centers, arboretums, Audubon centers, zoos, aquariums, museums, and district outdoor learning centers that provide professional development in science and make connections to other subjects such as mathematics. As a future research project, the overall effectiveness of professional development workshops and collaboration between classroom science teachers and informal science institutions should be studied. District science and STEM coordinators must understand the importance of their teachers and students making connections to real world science concepts. Informal science institutions must communicate with district science coordinators to learn about the most pressing science standards at the elementary, middle, and secondary school levels. An extension to my research on the relationship between formal and informal science educators would be to investigate the effectiveness of communication between informal science centers and school districts and relationship between teachers and students when they work with informal science institutions.

Reflection of Personal Growth and Future Agenda

The most rewarding part of this Capstone project was learning about formal classroom teachers' needs and being able to offer them a solution. Initially, I assumed that all teachers needed the same support in science education. Patterns emerged in elementary grade levels where classroom teachers need more science content and demonstrations on how to deliver activities in addition to their classroom textbooks for support in the classroom. Conducive to reach my goals as an informal science educator, I must learn how to approach teachers and offer them programs that support their students. Ideas I present to teachers must be easily translated into supplemental activities and not a burden on their already stringent requirements and possibly funding by their school, district, and the state. I have grown more patient and realized that most teachers want to connect with informal science institutions, but the timing may not be appropriate. I have been in situations where teachers reach out to me months after our initial conversation to work together.

The most difficult part of this Capstone was writing Chapter One about my personal experiences in the formal classroom setting and informal science field. However, I also realized the accomplishments and connections I made while I was in the classroom and in nature. For example, in my fifth grade science class, I used my tropical aquarium to investigate the increasing/decreasing water temperatures on my fish to create my science fair project on climate change or global warming. I accidentally turned up the dial on the aquarium heater and noticed that my fish started to lose their bearings. So, I investigated the point at which tropical fish can handle increasing and decreasing temperatures. I noticed that the connections I made on field trips to zoos, animal sanctuaries, and on vacations with friends and family provided a lasting impression on nature and the environment.

The most grueling task for Chapter Two was not only locating the literature through online university sites, but also being able to locate the research in the future. I found some amazing research on the working relationship between formal and informal science educators, which made me think if I am going to make a difference through my research on the topic.

After completing the first three chapters of this Capstone, I thought that I would be able to complete chapters four and five two weeks after collecting surveys from formal classroom teachers and interviewing science professionals. I soon realized that I needed to account for the time that I sent the survey or set up an interview and the time it would take to complete the survey and send it back to me. I thought that I would receive more than one hundred surveys, but received twenty to analyze.

Formal classroom science teachers from elementary to secondary grade levels face many obstacles, such as pressure from mandated standardized testing, availability to material to teach science in the classroom, and support from the school and district. Many elementary classroom teachers are forced to teach all subjects even though they may be stronger in subjects other than science. Those who favored science over other subjects become lead science teachers and eventually science coordinators. Many teachers at the middle and high school level have the content knowledge (for the most part), but also need support from the school and district. After meeting with many dedicated classroom teachers, I have learned that with the collaboration of informal science institutions and their schools, students in all grade levels and levels of interest will become more interested in science careers. Students need support from classroom teachers and informal educators to increase the number of students that enter science careers. The symbiotic relationship between formal and informal science educators can provide a rigorous and engaging science experience in the classroom and in nature.

REFERENCES

Avraamjdou, L. (2015). “Reconceptualizing Elementary Teacher Preparation: A Case for Informal Science Education.” *International Journal of Science.* v37 n1 p108-135. 28 pp.

Bozdogan, A. (2012). “The Practice of Prospective Science Teachers regarding the Planning of Education Based Trips: Evaluation of Six Different Field Trips”. v12 n2 p1062-1069. 8 pp.

Copely, L. (n.d) “Environmental Education in U.S. Public Schools: Fostering a Culture of Sustainability.” *Macalester College* http://www.macalester.edu/educationreform/reformcomposition/LainaRC.pdf

Committee on Science for EPA's Future; Board on Environmental Studies and Toxicology; Division on Earth and Life Studies; National Research Council. (2012). Science for Environmental Protection: The Road Ahead. Retrieved September 05, 2016, from http://www.nap.edu/catalog/13510/science-for-environmental-protection-the-road-ahead.

Creswell, John W. (2009). “Research Design: Qualitative, Quantitative, and Mixed Methods Approaches.” *University of Nebraska-Lincoln, SAGE Publications, Inc. 3rd Ed.*

DeWitt, J; Hohenstein, J. (Apr. 2010). “School Trips and Classroom Lessons: An Investigation into Teacher-Student Talk in Two Settings”. *Journal of Research in Science Teaching.* Vol. 47 Issue 4, p454-473, 20p

Dohn, N. (Nov. 2013). "Upper Secondary Students' Situational Interest: A case study of the role of a zoo visit in a biology class". *International Journal of Science education.* Vol. 35 Issue 16, p2732-2751, 20p

Feldman, A; Pirog, K. (Oct. 2011). "Authentic Science Research in Elementary School After-School Science Clubs. *Journal of Science Education and Technology*. Springer. Vol. 20, No. 5. Pp. 494-507. URL: http://www.jstor.org/stable/41499418

Fuller, R. (Dec. 2003). "Don't Tell Me, I'll Find Out: Robert Karplus: A Science Education Pioneer." *Journal of Science Education and Technology*. Springer. Vol. 12, No. 4. Pp. 359-369. URL: http://www.jstor.org/stable/40188741

Johnson, K; (Mar. 2015). "Museum Visits Can Bolster School Curriculum." *Principal.* Vol. 94 Issue 4, p36-37, 2p

Katz, P; McGinnis, J. (1999). "An Informal Elementary Science Education's Program Response to the National Science Education Reform Movement." *Journal of Elementary Science ducation. Springer.* Vol. 11, No. 1. Pp. 1-15. URL: http://www.jstor.org/stable/43155680

Katz, P; McGinnis, R. (Dec. 2012). "The Influence of Informal Science Education Experiences on the Development of Two Beginning Teachers' Science Teaching Identity." *Journal of Science Teacher Education.* Vol. 24 Issue 8, p1357-1379, 23p, 6 Illustrations

Kindfield, A; Singer-Gabella, M. (2010). "Inscriptional Practices in Undergraduate Introductory Science Courses: A Path toward Improving Prospective K-6 Teachers' Understanding and Teaching of Science." *Journal of the Scholarship of Teaching and Learning.* v10 n3 p58-88. 31 pp.

Kisiel, J. (Feb. 2013). "Introducing Future Teachers to Science Beyond the Classroom." *Journal of Science Teacher Education.* Vol. 24 Issue 1, p67-91, 25p, 4 Charts

Lakin, J. (Jan. 2015). "Assessing Dimensions of Inquiry Practice By Middle School Science Teacher Engaged in a Professional Development Program." *Journal of Science Teacher Education.* 26:139-162.

Mack, E; Augare, H. (Mar. 2012). "Effective practices for creating transformative informal science education programs grounded in Native ways of knowing." *Cultural Studies of Science Education.* Vol. 7 Issue 1, p49-70, 22p.

Mansour, Nasser (2007). "Challenges to STS Education: Implications to Science Teacher Education." *Bulletin of Science, Technology, and Society, SAGE Publications, Inc.*

Marable, S. (2015). "Green Schools - The Implementation and practices of Environmental Education in LEED and USED Green Ribbon Public Schools in Virginia. *Educational Planning.* Vol. 22, #1. P49-65, 17p. 100831496.

Markle, Amy J. (2008). "Adult environmental education programming in the Twin Cities metropolitan area related to critical natural resource issues." *Stephen F. Austin State University, ProQuest Dissertations Publishing*, No. 1458377.

Musante, S. (Sept. 2008). "Critical Conversations: The 2008 Biology Education Summit." *Oxford University Press*. Vol. 58, No. 8. Pp. 685-689. URL: http://www.jstor.org/stable/10.1641/6580804

Packer, J; Ballantyne, R. (2010). "The Role of Zoos and Aquariums in Education for a Sustainable Future." Issue 127, p25-34, 10p (EBSCO - website).

Ramey-Gassert, L. (Mar. 1997). "Learning Science Beyond the Classroom." *The Elementary School Journal. University of Chicago Press*. Vol. 97, No. 4. Pp. 433-450. URL: http://www.jstor.org/stable/1002356

Randler, C; et al. (June. 2012). "Adolescent Learning in the Zoo: Embedding a Non-formal Learning Environment to Teach Aspects of Vertebrate Biology." *Journal of Science Education and Technology*. Vol. 21, No.3. pp. 384-391. URL: http://www.jstor.org/stable/41499454

Riedinger, K; Marbach-Ad, Gili. (Feb. 2011). "Transforming Elementary Science Teacher Education by bridging Formal and Informal Science Education in an Innovative Science Methods Course." *Journal of Science Education and Technology*. Springer. Vol. 20, No. 1. Pp. 51-64 URL: http://www.jstor.org/stable/41499374

Roberts-Harris, D. (2014). "What Did They Take Away?: Examining Newly Qualified U.S. Teachers' Visions of Learning and Teaching Science in K-8 Classrooms." *Indiana University Press*. Vol. 2, No. 2. Pp. 91-108. URL: http://www.jstor.org/stable/10.2979/teachlearninqu.2.2.91

Sata, Yodi; Wongpho, Bounlert. (2015). "Development of a Learning Activity Management Model with the Community Learning Sources for Environmental

Education.” *United Nations Environmental Programme, American Scholars Press.* Vol. 11. Issue ½, Pg. 13-23, 11p.

Schwan, S; Grajal, A. (Apr. 2014). “Understanding and Engagement in Places of Science Experience: Science Museums, Science Centers, Zoos, and Aquariums”. *Educational Psychologist.* Vol. 49 Issue 2, p70-85, 16p

Simmons, P; Brunkhorst, H. (Jun. 2005). “Developing a Research Agenda in Science Education.” *Journal of Science Education and Technology.* Springer. Vol. 14, No. 2. Pp. 239-252. URL: http://www.jstor.org/stable/40188680

Specter, B; Burkett, R. (2012). “Derivation and Implementation of a Model Teaching the Nature of Science Using Informal Science Education Venues”. *Science Educator.* Vol. 21 Issue 1, p51-61, 11p, 3 Charts

Treagust, D.F., et al. (2015). “Science Teacher Education in Australia: Initiatives and Challenges to Improve the Quality of Teaching. *Journal of Science Teacher Education.* 26:81-69.

Tunnicliffe, S; Lucas, A. (Nov. 1997). **“**Record School visits to zoos and museums: a missed educational opportunity?” *International Journal of Science Education.* Vol. 19, p1039-1056, 18p

Velardi, Sara Hendrickson, et al. (Oct-Dec, 2015) “The Components of Effective Professional Development for Science Educators: A Case Study with Environmental Education Program Project Learning Tree.” *Applied*

*Environmental Education & Communication. V*ol. 14 Issue 4, p223-231. 9p. URL: http://www.tandf.co.uk/journals/titles/1533015X.asp

Weiland, I.S; Akerson, V.L (Dec. 2013). "Toward Understanding the Nature of a Partnership Between an Elementary Classroom Teacher and an Informal Science Educator." *Journal of Science Teacher Education.* Vol. 24 Issue 8, p1333-1355, 23p.

Weinstein, M; Ruble Whitesell, E. (Oct, 2014). "Museums, Zoos, and Gardens: How Formal-Informal Partnerships Can Impact Urban Students' Performance in Science. *SAGE, Publishing, Inc.* Vol 38, No.6.

Zhang, M; Parker, J. (Aug, 2015). "Understanding Inservice Science Teachers' Needs for Professional Development". *Journal of Science Education.* v26 n5 p471-496 Aug 2015. 26 pp.