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Informal science in the classroom: how informal and formal educational institutions support science instruction

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INFORMAL SCIENCE IN THE CLASSROOM:

HOW INFORMAL AND FORMAL EDUCATIONAL INSTITUTIONS SUPPORT SCIENCE INSTRUCTION

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MASTER'S THESIS

Abstract

Science education has seen a major overhaul with the implementation of ideas from the NRC's (2012) report, *A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas.* At the same time, we have seen a rise in the number of formal educational facilities partnering with informal facilities to bring these practices to students. This study explored the effect these blended approaches had on both student attitudes and their achievement in science content areas. To do this, surveys were designed to assess these areas in upper elementary students participating in a one-year blended science program. First, the literature was examined to develop themes around which the survey questions could be built. A sample, N=78, was pooled from anonymous student surveys returned after the program's completion. From this data, descriptive statistics and bivariate correlations were generated using SPSS software. While the research results did not support or disprove a relationship between attitude and achievement, it did show a positive correlation between a student's age and confidence in their ability to do science. A positive correlation between enjoying science and viewing science as a tool that makes sense of the world was also found. Professional development efforts should note that previous studies have shown growth in both attitude and achievement from blended programs and continue to research this area.

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CHAPTER 1

Introduction

The goal of this research was to explore the ways that informal educational facilities and formal educational facilities implement science instruction in the United States and, from that understanding, look into how a blended approach to science education affected student achievement and attitudes towards science. This was accomplished by studying the respective histories, goals, and practices of both formal and informal educational facilities, focusing primarily on public schools and science museums. In addition, I also investigated how the different pathways each type of facility took affected the people who experienced them, whether that be the general public or school groups. As my teaching background consisted of both informal and formal science instruction, I have seen firsthand the distinct differences in how instruction is approached, but I have also seen many similarities. Broadly, the two share the goal of increasing science knowledge in their communities. However, while formal institutions seek to help students meet structured content standards, informal institutions usually focus on inspiring curiosity and appreciation towards science, instead of imparting specific knowledge.

Due to their similar community-minded approaches, institutions of both types often share the same audience and sometimes work together to boost their goals. Part of what inspired me to explore this juxtaposition was my work at a local science center, where we had formed a partnership with public schools. In 2015 we were awarded a two-year state grant to fund a collaboration between several local school districts and the science center. Its goal was to work with low-income, rural, and Tribal schools in the area in order to design and implement a science curriculum about regional geological events and from multiple perspectives. This collaboration began during the 2015-2016 school year and consisted of relationship building, meetings with educators, and professional development for participating teachers and staff (Clevenger, 2016). I spent that year researching and building curriculum which explored how water affected our area, beginning from the Glacial Lake Missoula Flood during the last Ice Age and ending with humanity's modern relationship to the water through the Spokane Valley-Rathdrum Prairie Aquifer and hydroelectric dam energy generation. Because I was teaching this curriculum in traditional formal classrooms while acting as a representative of an informal science institution, I was inspired to explore previous partnerships between formal and informal facilities and the effect of this type of relationship on science pedagogical practices and student attitudes.

Significance of the Study

A decade ago, the National Science Board (NSB) (2007) published a report on the status of STEM learning within US public schools. The two main problems discussed were predicted shortcomings in the future job market and how disadvantaged the average citizen was in terms of even basic scientific understanding. This report was a catalyst for a number of studies into effective science pedagogy and by April 2013 the *Next Generation Science Standards* (NGSS Lead States [NGSS], 2013) were released. On October 1, 2013 Washington State became the eighth state to adopt the NGSS into its learning standards (renaming it the Washington State Science and Learning Standards) and began a four-year transition process for incorporating them into the schools (Office of Superintendent of Public Instruction, n.d).

The NGSS Adoption and Implementation Workbook, produced by Achieve and the U.S. Education Delivery Institute (2013), outlined seven main goals for districts to follow when implementing the new standards. These include creating a leadership team, analyzing science performance measures, setting measured goals for future performance assessments, and then checking back in on your accomplishments or setbacks. To reach these goals, districts provided professional development to administrators and teachers, held regular meetings to discuss results, and provided funding for new curriculum and materials (Achieve, 2017).

While the hope is that these new programs and procedures will yield improvements to Washington students' science understanding and scores on standardized tests, they also take a lot of time, money, and energy to implement. Lower-income and rural schools are less able to access the funding and collaboration critical for successful implementation. Yet, many communities already have established informal science institutions in their areas; could these two groups work together for mutual gain? As I began to research, it became clear this was not a commonly-utilized partnership. While there are hundreds of informal science facilities belonging to the Association of Science-Technology Centers alone, I could find only a handful of published reports on collaboration between these institutions and more traditional schools that went beyond an annual field trip ("Association of science-technology centers," n.d.). Nevertheless, both my research and the reviewed literature showed promising effects on student attitudes towards science after participating in programs that blended the instructional practices of both formal and informal institutions. My hope is that this research encourages more alliances in science education between museums and schools. As Johnetta Cole, former president of the Association of Art Museum Directors, spoke regarding informal and formal education partnerships, "I want to lift up the power of partnership by sharing with you the words of a wonderful African saying. 'If you want to go fast, go alone. If you want to go far, go together.' It's *good* going together" (as cited in Paulu, 2015, para. 6).

Statement of the Research Problem

The purpose of this thesis was to provide an overview of the history of science pedagogical practices within the United States, to explore the efficacy of symbiotic relationships between informal and formal science institutions, and to make recommendations on either utilizing, or avoiding, these partnerships in order to improve student attitude toward and understanding of science content. Many people feel that our current formal education systems are not doing enough for students when it comes to STEM, and those views are backed up by research. Monica Martinez, Senior School Strategist for the XQ Institute, an organization dedicated to rethinking public schools, argues that “with schools created for a world we no longer live in, we are not preparing students who are ready to claim their future” (as cited in Rolph, 2017, para. 15). The NSB (2007) noted that American students fall far below other industrialized nations on international assessments, such as the Programme for International Student Assessment test, and that nearly 30% of incoming college freshmen must take remedial STEM courses because they are not prepared for college-level courses.

Project Tomorrow (2007) found that 40% of students view science as important for their future decision-making, yet there is a significant difference in response rates when asking other stakeholders if students are being prepared for their future careers. While 57% of K-12 administrators felt their schools were doing well, teacher views dropped to 47%, parents down to 43%, and perhaps most importantly only 23% of students felt that their schools were preparing them adequately. I hoped to explore this avenue with the teachers participating in my program by asking them if they felt their students were prepared. Noting the differences between teacher views and administrative opinions, I also wanted to see how supported teachers felt by their administrations and if that affected their views on student preparedness.

Clearly something needs to change if we want our students to remain competitive globally while valuing the importance of STEM in their day-to-day lives and decisions. Perhaps a combination of the different approaches found in formal and informal education holds the key? Through my research, I hoped to find an answer.

Research Questions

To determine how these facilities approached science instruction, as well as how the communities that learned through them view science, my research was focused by three questions.

1. How have these institutions approached science instruction historically compared to now?
2. How do blended educational experiences involving both informal and formal partnerships affect student attitudes towards science?
3. How does a student's grasp of science content relate to their attitudes and future goals in science learning?

In Chapters 3, 4, and 5 I explored how both the literature and my own data collection answered these three research questions. In Chapter 3 Project Design, I presented my qualifications as a researcher, provided more detail about each site and its participants, and explained the rationale behind how I chose to structure my data collection and analysis. Chapter 4 Findings laid out the results of my collected data, presenting both the descriptive statistics and bivariate correlations analyzed. Finally, Chapter 5 Conclusions and Reflections presented an in-depth analysis of all of the data collected. From there I compared those results to the information found in the literature—highlighting areas supporting my findings. I also posited possible reasons my results do not always support what was found in the literature. Next, I discussed what I learned from conducting this research, the challenges I faced and how I would solve them if given another opportunity. Finally, I suggested different avenues for further study related to the research questions and literature.

Limitations of the Study

While I synthesized a broad range of scientific instruction across the United States in my literature review, I focused primarily upon K-12 age groups and excluded university students. Because the grant partnership I worked through only served elementary schools, the survey research I conducted was limited to upper elementary students (Appendix A) and their teachers (Appendix B). Due to the short timeframe I had with which to work with these students, as well as a lack of access to their test score records, I was only able to assess student attitudes towards science and could not explore achievement levels or progress academically. Furthermore, since I did not have access to students outside of the classrooms who chose to participate in this grant, I lacked a control group with which to compare the collected data results of students who participated versus students who did not.

My original plan was to give the survey twice to both students and teachers: once before I began teaching the curriculum and again at the end of the school year. Due to a combination of differing start times for the partnership and delays within the Institutional Review Board process, I was only able to conduct a single survey at the end of the year. I had also hoped to explore teacher attitudes and pedagogy. My teacher survey asked questions exploring the relationship between teacher experiences, their pedagogical practices, their attitudes towards science, and their levels of support and training. Unfortunately, only two teachers out of six returned the surveys. Because of the small sample size, I did not feel confident in drawing conclusions from the data set.

Definition of Terms

There are several terms which appear in this thesis that have meanings specific to the context of this research. To aid with clarity, what follows is a list of terms with their definitions, as they apply to this study.

Formal Education/Learning: Education provided by trained teachers in a systematic manner usually prescribed by local or national educational standards and curriculum (NSB, 2010). For this study, I focused primarily on science instruction, but also included the other STEM content areas of technology, math, and engineering when the literature supported connections.

Formal Science Facility/Institution: The locations where formal education takes place. For the purposes of this study, that included both public and private K-12 schools, as well as higher learning institutions such as universities and colleges (NSB, 2010).

Informal Education/Learning: Often conflated with non-formal learning, informal learning in this context is learning which takes place in an environment that is less structured than formal learning. This may include, but is not limited to, learning that is more self-guided and/or dictated by interests instead of standards. Community-based activities, such as citizen science initiatives, are included as well. While informal learning can consist of any subject, for the purposes of this study science was the focus, but I also included the other STEM content areas when warranted (National Research Council [NRC], 2009).

Informal Science Facility/Institution: The locations where informal learning takes place, limited in this study to museums, science centers, zoos, aquariums, and after school programs (NRC, 2009).

STEM: An acronym designed to show the science, technology, engineering, and mathematics content areas and their interdependency.

CHAPTER 2

Literature Review

This literature review sought existing research available regarding science pedagogical approaches in both informal and formal educational facilities. The first section presents the history of science instruction and its implementation in the United States of America, focusing specifically on formalized instruction within the classroom. The second section explores informal institutions, primarily focusing on museums, and their changing role in science communication as educational institutions. Finally, this review investigated partnerships between informal and formal institutions, analyzed their efficacy, and looked at new ways the two can support each other.

Science Instruction through the Years

"Science teaching has suffered because science has been so frequently presented just as so much ready-made knowledge, so much subject matter of fact and law, rather than as the effective method of inquiry into any subject matter" (Dewey, 1910, p. 124). While this quote would not be out of place in any modern article on science education, it was written by educational reformer John Dewey over one hundred years ago. Unfortunately, his forward-thinking ideas towards science education would be largely ignored until the late 1950s. Previous legislation for federal funding of education had failed, but the Cold War would provide a new angle to sell education through: national security and defense (Bentley, E.S. Ebert, & C. Ebert, 2007).

Spurred by the launch of Sputnik and the low exam scores of enlisting US troops, the National Defense Act of 1958 was signed into law on September 2nd (Bentley et al., 2007). Through it, millions in federal funding were spent on STEM curriculum, teacher professional development, and college loans. Over the next decade, college enrollment would double and nearly two billion dollars were spent on science education curriculum and initiatives. These reforms would be significantly different than previous efforts, led by scientists with the intention of bringing the skills and knowledge that real scientists used to students (NRC, 2007; Yager, 2000).

Initial programs focused on secondary education, but shortly after trickled down into elementary education with the so-called "alphabet soup programs" of the 1960s, nicknamed for their nomenclature of long strings of acronyms. The Elementary Science Study, Science Curriculum Improvement Study, Science: A Process Approach, Man: A Course of Study, the Intermediate Science Curriculum Study, and the Conceptually Oriented Program in Elementary Science (ESS, SCIS, SAPA, MACOS, ISCS, and COPES respectively) were designed by university teams to focus on hands-on learning that relied on using real science tools, such as Geiger counters and cloud chambers, and actual data to mimic the processes that laboratory scientists did in their research (Bentley et al., 2007). However, while efforts were being made to move away from the empiricist model and towards an inquiry-driven pedagogical approach, the curriculum and practices still focused heavily on direct instruction straight from textbooks (NRC, 2007; Yager, 2000).

Unfortunately, the heyday of government funding in the 1960s waned by the 1970s as anti-science sentiment began seeping into deep-seated political and racial tensions. Epperson v. Arkansas' ruling that barring evolution education was unconstitutional did little to quell the issue for many in America. In a controversy that feels all too familiar to modern readers, MACOS faced the ire of a small-town conservative preacher in 1970 (Slater Stern & Kysilka, 2008). What started as radio shows decrying MACOS as nothing but "sex education, evolution, a 'hippieyippee philosophy,' pornography, gun control, and Communism…a threat to democracy" (Slater Stern & Kysilka, 2008, p. 145), eventually spread into full Congressional investigations into the National Science Foundation (NSF). This led to a sharp cut of funding for STEM curriculum development and tightened purse strings for funding elsewhere. Both the political and financial costs connected to the material-heavy kits ensured that only a small number of districts implemented these new programs. Eventually, many who did utilize these curricula went back to their previous practices (Bentley et al., 2007). In 1982, President Reagan would slash NSF funding by 70%, seeing an end to all NSF K-12 science education supports and curriculum development (Hechinger Report, 2011). While the 1983 publication of *Nation At Risk,* showing "disturbing inadequacies" (National Commission on Excellence in Education, 1983, Findings section, para. 1) in the educational attainment of US students, would lead to the restoration of some funding, by the end of the '80s science education would be back squarely resting on textbook lessons.

But the peril recognized in increasingly low education scores would swing focus once more on STEM practices. The NRC (1989) released two reports arguing that our security and standing as nation was at-risk (Madison & Hart, 1990). The political opposition it had faced in the previous decades led the NSF to focus its efforts and funding on the science of learning (Yager, 2000). National standards for both math and science would be released by 1996 (NRC, 1996). These standards included research from a new branch of science focusing on how people learn, pioneered through funding from the NSF: cognitive science. This multidisciplinary approach to learning would greatly expand and deepen researchers' abilities to understand the observable behavior of students, to formulate new theories of learning, and explore new avenues for delivering instruction (NRC, 1999). The NRC's (1996) report would include four goals for students to execute during their lessons: (1) experiencing the excitement of understanding the natural world, (2) using appropriate scientific processes when making personal decisions, (3) using scientific literacy to contribute to civil discourse, and (4) increasing their economic opportunities through science literacy and understanding. The National Council of Teachers of Mathematics (1989) added to these goals, focusing on the social aspects of learning and the importance of science literacy, instead of simply laying out straight-forward content for students to either meet or fail to achieve. They pushed for "(1) mathematically literate workers, (2) lifelong learning, (3) opportunity for all, and (4) an informed electorate" (p. 3). They presented a radical new approach to learning, turning away from the traditional memorize and repeat method and pushing instead for conceptual understanding.

Despite the ongoing politicization of STEM education, the push for reform which gained a foothold in the 1990s would continue to gain momentum. While the utilization of real data and inquiry-based science education had begun in the 1960s, the addition of the social currency found in the National Council of Teachers of Mathematics' standards expanded into the concept of curriculum integration (Hechinger Report, 2011; Konicek-Moran & Keeley, 2015; NSB, 2007; Slater Stern & Kysilka, 2008). With an inquiry-driven goal in mind, it would not be enough for our students to focus solely on pure science, they needed to know how to use their knowledge for the real-world issues that resonated with them. James A. Beane (1995) described curriculum integration as "the search for self- and social meaning" (p. 616). Curriculum integration advocates pushed for educational attainment through the use of organic problems that allowed students to explore issues meaningful to them and their own communities and to use their knowledge to present solutions, fitting neatly alongside inquiry-based practices (Konicek-Moran & Keeley, 2015).

Sanders (2009) defined curriculum integration as "approaches that explore teaching and learning between/among any two or more of the STEM subject areas, and/or between a STEM subject and one or more other school subjects" (p. 21). While research into the efficacy of science education initiatives remains light, new studies are completed each year. A study by Fortus, Krajcik, Dershimer, Marx, & Mamlok-Naaman (2005) showed a statistically significant jump in understanding for students exploring an engineering unit with real-world setting and design choices. Riskowski, Todd, Wee, Dark, & Harbor (2009), found similar results in a study using a middle-school water resources curriculum. The positive effects of this pedagogical approach seem long-lasting, with some students showing growth up to two years after the end of the curriculum (Geier et al., 2008). While their numbers are still low, the few statewide, longitudinal surveys on student achievement have also consistently shown growth, especially for traditionally underrepresented racial minority groups (Geier et al., 2008; Hansen & Gonzalez, 2014). A stronger correlation between academic achievement and the participation in this program type was shown in elementary classrooms than was found in secondary classrooms, but further research is needed to understand why elementary students' scores seem to be more strongly correlated than older students' scores.

Because of the growing body of research supporting inquiry-based pedagogy, it is not surprising that contemporary pushes for national science standards emphasize inquiry and integration. The NSB (2007) released a comprehensive outline for tackling current issues in STEM education within U.S. public schools. An important facet of this was their recommendation for was what they call "horizontal coordination of STEM education among states" (p. 9) by designing and implementing science standards across the nation for each grade level. Their recommendations came with dire declarations of the failure of previous standards-based reform efforts. Science courses, even with open-ended laboratories and inquiry-based foundations, were found to still overemphasize the memorization of facts instead of bringing students into actual questioning and interpretation (NRC, 1999; Yager, 2000). Bybee's book *Reforming Science Education: Social Perspectives and Personal Reflections* (as cited in Nollmeyer, 2014) notes that "there have been widespread efforts to change drastically the purposes for which science is taught. For the most part, reform has remained an illusion; the traditional mold has not been broken" (p. ix). In many places, students still complain that textbook-based science laboratories require "no imagination or creativity at all!" (Ayer, 2015, p. 1665). With this in mind, the NRC (2012) developed the *Framework for K-12 Science Education*. Writing from this Framework, the NGSS Lead States (2013) developed the *Next Generation Science Standards: For States, By States*. The blending of core science ideas, scientific practices, and crosscutting concepts expected in the NGSS should push teachers to abandon the textbook-focused pedagogy of the 1980s and embrace inquiry-based, integrative approaches.

Moore (2014) notes that the NGSS provide ample opportunities for integrative learning. She further classifies this integrative approach into two categories: context integration and content integration. The former refers to "an integration of…design as a motivator to teach some discipline" (p. 5) with the goal being to understand processes surrounding content. On the other hand, content integration combines thinking with STEM content where "learning multiple areas…are part of the learning objectives" (p. 5). Of import, she urges that science educators use the NGSS to "give relevance to all content areas and [be] more representative of the problems that our society faces" (p. 6). Despite all this, classroom pedagogical practices remain slow on the uptake. Could partnering with less formal, but still research-based, educational programs spur the change our students need to finally improve their conceptual understanding of science?

Informal Science Education

Informal learning can best be described as the everyday questions and revelations we have as we move about our lives (NRC, 2009; Sacco, Falk, & Bell, 2014). Informal science education is often spontaneous: an exploration of botany while picking berries or gardening with one's family, seeking information on anatomy after an injury or medical issue (NRC, 2009). Banks et al. (2007) point out that, even at the point when students are most heavily-involved in formal educational learning during grades 1-12, over 80% of their time is spent in informal learning environments. Even though they are not heavily structured, these opportunities are ripe for cognitive activities and their deep connection to the cultural ties of the communities they reside in can help counteract the racism and discrimination disadvantaged or non-minority groups often face within the more institutionalized hegemony of formal educational facilities (Banks et al., 2007). For the purposes of this paper, research was confined to what the NRC (2009) calls "designed settings," locations that have been specifically tailored for a purpose. These are heavily-centered around participants, but also reflect the educational goals of the institution itself. The role of the guiding teacher in a formal classroom is often replaced by objects and labels and usually allows for self-guidance, with some occasional nudging from interpreters. Rowe (as cited in Atkins, Velez, Goudy, & Dunbar, 2009) notes how the organizational choices museums make show participants "how one should proceed in order to live out the suggestions of the museum authority as represented by its voice embodied on the label" (p. 168). However, the casual nature of informal science programs allows for significantly greater interaction and choice on behalf of the participant when compared to formal programs.

While traditional formal education institutions are still struggling to leave the teacher lecture model, in many informal educational programs the collaborative model is a natural result of the more casual nature. With less focus on an end-of-unit content assessment, students have more freedom to collaborate, to take time to organize themselves, to brainstorm solutions, and to take ownership of their products (Ayer, 2015). This freer environment is a great place to generate intrinsic motivation and a stronger desire to pursue science learning on their own time, or even as a future career (Ayer, 2015; Bamberger & Tai, 2008; Csikszentmihalyi & Hermanson, 1995; Salmi, 2003).

The NRC (2009) conducted a review of informal science programs and their effect on learning. They broke it into six categories of science learning: heightened excitement, interest, and motivation; generating and understanding concepts and models; manipulating, testing, and observing the world; reflecting on science processes and concepts as ways of learning about phenomena; engaging in scientific activities with others using appropriate language and tools; and thinking about themselves as science learners who contribute to science. Konicek-Moran and Keeley (2015) note that while informal education opportunities are all around us, whether it be noticing any kind of natural occurrence or event around us and asking questions or simply being curious about the phenomenon, only recently have researchers begun investigating its value as an educational model. Indeed, because informal science education can be so broad, this literature research will focus on the slightly more formalized formats of educational media, science museums, and social media outreach models of informal science education.

Traditional Educational Media

Before Sputnik launched the first national conversation on science education in the classroom, programs like *Watch Mr. Wizard* were introducing scientific concepts to families from the comfort of their living rooms. During its original broadcast from 1951-1965, *Watch Mr. Wizard* brought intriguing but replicable-at-home experiments to millions of viewers ("Watch Mr. Wizard," n.d.). By 1956, it had spawned over five thousand science clubs bearing its namesake (LaFollette, 2002). A study of 210 participants discovered that watching an episode of *Watch Mr. Wizard* led to viewers performing an average of 61% better on a post-test compared to their pre-test scores on science content (Whittle, 1997). The 1960s and '70s brought us classics still running today, such as *National Geographic Specials, NOVA,* and the *Wild, Wild World of Animals* (Whittle, 1997). The 1990s saw *Bill Nye, The Science Guy* and *The Magic School Bus,* both of which have had 2010s' revivals.

In 2016, the average American watched 5 hours and 4 minutes of television a day, so it comes as no surprise that it's a big business (Koblin, 2016). Millions of dollars are spent annually on informal educational media, from both government and corporate sources, resulting in a huge number of people turning to it weekly (Rockman et al., 2007). Many science education providers can boast strong support. For instance, 8% of PBS' supporters watch at least eleven hours of content each week while NPR's listenership continued to grow to an estimated 20 million every week in 2003 (Rockman et al, 2007). The high accessibility of informal science programming, such as PBS and NPR, is a huge selling point. Rockman et al. (2007) places broadcast media and internet as the top two media types in terms of access, noting the ease of broadcasts that go directly into viewers' homes and that nearly 233 million people in the U.S. have internet access. While access to educational materials and quality teachers regularly stymie STEM understanding and engagement in low-income or rural schools (NSB, 2007), anyone with television, radio, or internet access can consume quality informal educational media. Whittle (1997) found that 99% of Americans had a television in their home and Rockman et al. (2007)

notes that 40 million people in the U.S. use the internet as their primary source of information. Informal science media is not constrained by standards, with an “implicit rather than explicit pedagogy” that allows it to be more responsive to current issues.

Several studies on the efficacy of informal science media show positive findings, especially in terms of boosting viewers’ attitudes towards science. A study by Pezdek, Lehrer, & Simon (as cited by Whittle, 1997) found that elementary students learning through television learned equally as well as students who absorbed material through reading. Whittle (1997) noted that in multiple studies, children were able to draw more inferences and remember more content when presented it visually through television, when compared to reading it. Increased favorability towards science, believing that science played a positive role in changing our world, and more confidence in their own knowledge have all been attributed to regular viewing (Rockman et al., 2007). Rockman et al. also found that 74% of viewers acted after engaging with media, either discussing the content with someone else, doing a related science activity, or searching for additional information on the topic.

Museums

Museum exhibits attract very broad audiences ranging from young children to seniors, individuals to groups. In larger museums, single science shows can attract thousands of people at one time, with the chance to see science in a theatrical and engaging light being a major draw (Roche, Cullen, & Ball, 2016). In North America, over 140 million people visit informal STEM museums, such as aquariums, observatories, zoos, and science centers annually. This is more than the top four organized sports’ attendance combined (Schwan, Grajal, & Lewalter, 2014). Because of this large audience, museums form an important aspect of our everyday science literacy.

The unique ability of museums to connect the public with real-world phenomena and issues makes them frontline points for real-world STEM inquiry. Because of the increased freedom and choice when interacting with STEM concepts in museums, as opposed to formal classroom settings, museums can also provide deeper connections for culturally-relevant experiences and increased participation for non-English speakers and those with lower science background knowledge (Ng & Montano, 2016).

To handle diverse audience needs, museums focus on "authenticity, stagecraft, and variety" (Schwan et al., 2014, p. 72). Access to cutting-edge tools, artifacts ranging from prehistory to contemporary times, and even living creatures are all widely available at museums across the country. Unfettered by a need for standards-based content mastery, they can add flair and unanswered questions that pique curiosity and connect emotionally. While knowledge may not be retained as deeply, positive attitude shifts towards STEM content holds true for visitors even six months after their visit (Hein, 1998). The fluid and self-guided approach to museums allows "visitors [to be] empowered to know and speak in ways that are meaningful to them" (Roberts, 1997 as cited in Banks et al., 2007, p. 2).

The social nature of museums provides a variety of outcomes depending on the context. For instance, children spend more time interacting with exhibits when they are with their parents, as opposed to their peers or alone (Tare et al., 2011). Children whose parents provide short explanations develop a deeper understanding of content. While they can understand physical and procedural information through their own hands-on exploration, complex concepts require short informal explanations, of which museum labels often provide (Fender & Crowley, 2008). The continuation of these unstructured family conversations is often found at home, deepening and expanding knowledge and real-world connections for participants (NRC, 2009).

Museums, lacking the set timelines and course outlines of formal education, allow visitors to follow their own path, engaging in whichever exhibits interest them and spending as much time as they like at each one (NRC, 2009). To do this, they often rely on a “hook” of sorts to capture the audience’s curiosity (Csikszentmihalyi & Hermanson, 1995). These hooks are frequently the exhibits but may also be posted questions. While formal learning facilities focus on external motivators, such as grades, informal learning facilities focus on intrinsic motivators and thus can lead to more long-term affective gains for visitors (Csikszentmihalyi & Hermanson, 1995). School field trips can often be so memorable that they inspire students to pursue science careers as adults (Salmi, 2003). Bamberger & Tai (2008) interviewed a group of 8^{th} grade students sixteen months after a field trip. They found that students still could recall facts, such as explanations provided by staff or displays, and details of their experience that they felt provided value to them even after time had passed. A study by Knapp (2000) found similar results up to 18 months after the visit.

By posting questions, designing immersive activities, and providing opportunities for participants to ask and discuss their own open-ended questions, museums increase the conceptual understanding of varying STEM content found within their exhibits (Yoon, 2013). While a regular visitor usually engages in museums very casually, guided by their own personal interests instead of museum staff leading them, field trips often benefit from additional structure (NRC, 2009). Knowledgeable staff can facilitate conversation, ask questions, and encourage students to come up with hypotheses or insight about exhibits (Serrell, 2006). By encouraging students to converse, offer possible explanations, and explore exhibits, field trips can be great tools for students to improve their conceptual understanding of a variety of scientific ideas (Atkins, Velez, Goudy, & Dunbar, 2009). A significant portion of students in the United States visit informal science facilities each year. In one study of 7^{th}-12^{th} graders, two-thirds of the students reported visiting at least once a school year while nearly 40% visited more than once (Sutter, 2014).

Using similar frameworks to the NRC's (2009) six strands, many studies have found positive relationships between science attitudes and/or content knowledge after students visited an informal science facility (Suter, 2014; Tenenbaum, To, Wormald, & Pegram, 2015; Whitesell, 2016). Suter (2014) found that high school students who regularly visited informal science facilities scored higher on science tests in Grade 12; this correlation was even more significant than that between student achievement and parents' education levels. This could lend credence to the idea that field trips may help reduce the gap between students with both disadvantaged and advantaged backgrounds, but additional research is needed. Furthermore, this study found that test scores increased slightly with each visit to a science museum. However, no such change was observed for students who visited other types of informal facilities, such as aquariums, zoos, or non-science museums (Suter, 2014). Whitesell (2016) focused on the effect of field trip visits on traditionally underserved student groups, specifically Hispanic and students on free or reduced lunch programs. While they found a positive shift in academic achievement for all students who participated in field trips, the underserved students saw significant growth. Considering field trips are such an insignificant time investment, to have such a measurable positive impact shows just how valuable these visits are.

Unfortunately, museums are seeing their traditional educational connection, the K-12 field trip, decline. The Field Museum's numbers decreased by a third over the last decade and the American Association of School Administrators found that over half of all schools eliminated field trips entirely in the 2010-11 school year (Greene, Kisida, & Bowen, 2014).

Museums and Social Media Outreach

Perhaps to combat this decreased interaction, informal science facilities are increasingly turning to social media outreach. Some museums frame their exhibits as backdrops for photos, like the Los Angeles' attractions "Yayoi Kusama: Infinity Mirrors" or the Museum of Ice Cream. These exhibits feature selfie timers in rooms and focus on "building a space that exists primarily for replication online" (Hobson & Pardes, 2017, 4:43). Others focus on building a relationship with their visitors online, allowing a real-time dialogue to occur (Gonzalez, 2017). Informal science facilities, such as the Sydney Observatory, are able to post clarification or information on current events, including email hoaxes or short-lived viral memes. In one example, the observatory responded to incorrect information circulating about a current astrological event. The single post on Facebook received hundreds of responses, many displaying a public that had previously accepted the misconception but now credited the observatory with "setting the record straight" (Russo, Watkins, Kelly, & Chan, 2006, p. 2) The authors described this as a shift from traditional one-to-one or one-to-many communication models, in which the museum's authority provides an audience with interpretation based on an exhibit, to a many-to-many model wherein an entire community can work together on a huge array of topics, guided by a museum figure (Russo et al., 2006).

Museums can build anticipation by taking the public behind the scenes of upcoming exhibits, they can gather feedback to correct misconceptions, or plan future exhibits which are more enticing for their communities, all by using social media to communicate with their audience. They can offer deeper perspectives and educational opportunities that may not be possible for a physical museum. The former chief digital officer of the Met, Sree Sreenivasan, argues that people "want to get a sense of how things are made…rather than just sit on something and have it appear" (Gonzalez, 2017, para. 2). The Field Museum's Emily Graslie brings the public into research rooms, explores non-displayed collections, and answers viewer questions through Twitter, Facebook, and her YouTube channel titled The Brain Scoop (Field Museum, n.d.). Both Graslie and The Brain Scoop are extremely popular; her Twitter account has nearly 90 thousand followers (Graslie, n.d.) and The Brain Scoop boasts almost half a million subscribers (The Brain Scoop, n.d.).

Social media interaction may help remove traditional barriers to informal science facilities and increase the audience that can interact with them. Museum attendees tend towards white middle- to high-income families in urban areas (Dawson, 2014). What then of minority students, those with lower incomes, or those who live in rural areas far away from informal science facilities? Among other things, cost, coordination, and a lack of supervision could all be contributing factors to the decline of field trip attendance. While the Met receives about six million in-person visitors a year, their website receives 29 million hits, and their Facebook outreach hits 92 million people a year (Gonzalez, 2017). While it remains to be seen what effect purely digital interaction with informal science facilities has on the attitudes and learning of students, it could be an effective way to bypass access barriers and allow students to see the benefits found in physical field trips.

Efficacy of Partnerships: Beyond Field Trips

In recent years, some communities have begun participating in partnerships between informal science facilities and formal educational institutions that go much deeper than individual field trips. In a study comparing high school students who participated in the Great Debate program at a natural history museum, a four-part workshop focused on evolution, and students who did not participate, noticeable changes in understanding were found (Tenenbaum et al., 2015). Students were introduced to the debate frameworks around Darwin's *Origins of Species* from multiple contemporary viewpoints, they examined museum specimens to draw their own conclusions in order to support either an archetypal model or the common ancestor theory, they debate each other while taking up the role of famous 19th century scientists, and finally they participate in lessons on the importance of peer-review and how evidence can lead to different viewpoints. By comparing pre- and post-test scores and analyzing participant interviews, researchers were able to find a statistically significant difference between students who had participated and those who did not. The students who had participated in the Great Debate program were able to discuss evolutionary processes and newly presented evidence by drawing on scientifically accurate data, while students who did not participate were limited to generalized or pseudoscientific evidence (Tenenbaum et al., 2015).

Some museums, like the one hosting the Great Debate series, increase participation through themed workshop offerings. On the other hand, some museums are extending their interaction with students into year-long, or multi-year, programs centered around community collaboration. Three of those programs are KQED Science Quest, NE STEM 4U, and Urban Advantage.

KQED Science QUEST

QUEST is a Bay Area, California community project that works to generate and guide discussions relating to local issues on science, nature, and the environment (Bandy & Fung, 2009). Over the course of three years, they conducted a survey to analyze its outreach and efficacy in promoting quality environmental science collaboration throughout the community. These activities ranged from media content, such as an online presence, radio and television broadcast, professional development for teachers, and science workshops for students. To review its programming, QUEST administered two audience surveys in their first year, then recruited a sample of respondents to continue participating over the next two years in a longitudinal study. While their study looked at their entire community, for this literature review only the educator and student portions of the evaluations will be examined.

Over the course of the first two years of the program, QUEST conducted observations, pre- and post-professional development surveys, and case studies with the participating teachers. The teachers in the research cohort were divided into grade level and subject taught; about half taught K-8th grade science while the other half taught 9-12 science. QUEST sought information not only on the efficacy of their offerings, but to see how educators used the materials in their own classrooms. For the third and final year of the study, administrators added an examination of the 2008-2009 Science Education Institute and additional questions which investigated how educators specifically used the online resources (Bandy & Fung, 2009).

Their data collection showed that more than a third of the teachers used QUEST content in their classrooms multiple times each month, predominantly video segments and Educator Guides for lesson ideas. Online content has grown into a very popular resource in the community with the web site receiving 55,000 visits monthly and audio or video content being streamed on average 100,000 times a month. By using resources from this informal science institution, teachers felt that their students were more engaged with their science lessons and that significant value had been added. TV broadcasting, video, websites, digital maps, and/or lesson plans were each used in their regular science instruction by at least half the educators surveyed. One of the top benefits reported was the availability of quality, cutting-edge content in contrast with often outdated textbooks or curriculum (Bandy & Fung, 2009).

In the third year, QUEST added a Science Education Institute. Its main goal was to increase access to current, engaging science content for Bay Area schools through technology and digital information. This two-day program involved instructional and collaborative time for teachers to individually tailor the materials to their own classrooms. Participants were required to establish on-going collaboration at each participating school in order to continue developing lessons and supporting each other. Almost 90% reported positive effects on student learning and engagement after utilizing material and training from the Science Education Institute (Bandy & Fung, 2009).

NE STEM 4U

In 2013, the Nebraska Science, Technology, Engineering, and Mathematics 4U program (NE STEM 4U) began through the University of Nebraska at Omaha (Cutucahce, Luhr, Nelson, Grandgenett, & Tapprich, 2016). This program offers project-based learning activities for K-8 students twice a week after school during the academic year. While the curriculum is based on the school's materials, NE STEM 4U brings in community partners to enhance learning in an informal setting. The instructors are all undergraduate students from the University of Nebraska at Omaha and act as mentors for "a future generation of STEM students with their outreach" (Cutucache et al., 2016, p. 2). The program was designed to target students who are low-income, low-achieving, or from underserved communities in order to boost their academic achievement in STEM content areas.

While academic goals are two of the main targets for NE STEM 4U, social-emotional goals are also heavily emphasized. The program works to decrease behavioral issues resulting from a lack of safe, structured activities and shift authority and responsibility onto the participants. Every activity uses either common household items or provides additional materials for students so they can teach their families at home. Not only does this increase the sense of ownership for students in their own learning, but it improves their communication skills and nurtures a community interest in science literacy (Cutucache et al., 2016).

The program shows huge potential in improving both students' conceptual understanding of the science content introduced and in attitudes towards science learning. Not only did participating students show an average growth of twofold in academic achievement, but they performed significantly better on long-term retention of content when compared to a non-participating control group of students. Self-reported confidence levels and interest in attending college also showed an increase in K-8 participants. Surprisingly, even the undergraduate mentors showed an increase in self-reported confidence and communication skills while nearly 20% decided to change their majors to focus on science education after teaching in the program (Cutucache et al., 2016).

Urban Advantage

Urban Advantage is a massive community partnership between public school districts and local informal science facilities with locations in both Denver, Colorado and New York City, New York. In Colorado, the top three public school districts have partnered with the Denver Botanical Gardens, the Denver Zoo, and the Denver Museum of Nature & Science. In New York City, the NYC Department of Education works with the New York City Council, the American Museum of Natural History, the New York Botanical Garden, the Bronx Zoo, New York Hall of Science, the Brooklyn Botanical Garden, the New York Aquarium, the Queens Botanical Garden, and the Staten Island Zoo. These partners work to support over 30% of New York City middle schools (Urban Advantage, n.d.).

Urban Advantage targets middle-school students and hopes to improve their grasp of scientific understanding and inquiry through collaborations with informal science facilities. These informal facilities allow students to explore and experience immersive, hands-on, real-world science activities that the public schools cannot provide on their own. Their model is based on six components: (1) quality professional development for educators and administrators, (2) authentic classroom materials and resources, (3) access to participating informal science facilities through zero-cost school and family field trips, (4) community outreach that involves families and celebrates student achievement, (5) a capacity-building network designed to support schools and teachers, and (6) assessment of the program goals and student learning (Urban Advantage, n.d.).

Urban Advantage resources and workshops strive to bring scientific inquiry into the classroom, incorporating opportunities for students to generate their own explanations from collected evidence and both communicating and evaluating both their own and their peers' conclusions (Urban Advantage, n.d.). Such efforts align well with the NRC's (2000) expectations for inquiry. The Urban Advantage (n.d.) program works throughout the academic school year to ensure students work in conjunction with programs and staff at partnering informal science facilities to design and conduct student-led exit projects. These exit-projects can include, but are not limited to, field studies, secondary research from authentic scientific data sets, and controlled experiments. During this work, teachers also gain skills from a two-year professional development program that is designed to offer support and resources even after the two years of training is complete. Additionally, teachers receive a paid stipend to incentivize workshop attendance (Urban Advantage, n.d.).

Urban Advantage has been running since 2005 and consistently provides excellent results. Students participating in the program outperform non-participating students in their 8th Grade Intermediate Level Science Test. Multiple years showed Urban Advantage students earning nearly 10% more than their control group cohort (Urban Advantage, n.d.; Weinstein, Whitesell, & Schwartz, 2014). Additionally, Weinstein & Shiferaw (2017) found that teachers who participate in Urban Advantage programs and professional development are 3% more likely to remain at their schools the following year, compared to non-participating educators. This increased retention jumps to 16% if the teacher has 3-5 years of teaching experience.

Conclusions

Science education has seen significant changes in the United States over the last half century. However, these reforms are often reactionary actions taken due to geopolitical threats, plagued by political argumentation, and rarely last long enough to lead to improvement in student achievement in science conceptual understanding (Konicek-Moran & Keeley, 2015; NRC, 1999, 2012; NSB, 2007; Yager, 2000). However, the NGSS (2013) represent a nationwide, massive overhaul of our approach to science instruction. The goal is to combine core science content with authentic practices and cross-cutting concepts that bring inquiry-based learning opportunities to science classrooms (NGSS, 2013).

This new reform initiative complements the curiosity-driven and unstructured learning commonly found in informal education. Informal science education is only recently receiving the recognition it deserves as a major contributor of scientific literacy and curiosity for students across the globe. While the studies are still limited and often shallow, the available research shows that informal science education has strong positive correlations on student achievement and attitudes towards science, especially for traditionally underserved students (Ayer, 2015;

Banks et al., 2007; Bentley et al., 2007; Csikszentmihalyi & Hermanson, 1995; Ng & Montano, 2016; NRC, 2009; Sacco et al., 2014; Suter, 2014; Yager, 2000).

A few communities have taken this research and used it to establish much larger-scale partnerships between their formal public school systems and informal science facilities. These programs lead to growth in both student and facilitator attitudes towards science (Cutucache et al., 2016), increase student scores on science assessments (Bandy & Fung, 2009; Cutucache et al., 2016; Tenenbaum et al., 2015; Urban Advantage, n.d.; Weinstein et al., 2014; Whitesell, 2016), and even show specific growth in traditionally underserved student populations (Weinstein et al., 2014; Whitesell, 2016). While these programs are still only a few years old and the body of literature assessing their efficacy is nascent, what we do have is enough to warrant additional research and the continued utilization of these informal-formal educational community partnerships.

CHAPTER 3

Project Design

Introduction

The goal of this research was to address how informal and formal educational facilities can complement each other in support of student attitude and achievement. Three main research questions came from current literature analysis which guided the direction of this study:

1. How have both public education and informal science institutions approached science instruction historically? How has that changed in the modern era?
2. In what ways do instructional practices affect student attitudes towards STEM content?
3. How does the understanding of science content a student has influence their attitudes and future goals towards science?

Both quantitative and qualitative data were collected for this study through written-response surveys. Students who participated in the iGrant blended program were asked about attitudes towards science and science instruction. The student survey (Appendix A) included ten Likert scale questions and three open-ended questions organized around student attitudes and usage of STEM both in and out of the classroom. Teacher surveys (Appendix B) were also used to collect teacher perceptions of various pedagogical practices, their support from administration and professional development in regard to science instruction, and their attitudes towards science. These surveys asked twelve open-ended questions regarding their personal qualifications, the materials and concepts they used in their regular science instruction, and what they believed the biggest issues in science education were today. In addition, there were 19 Likert scale questions asking teachers to rate their familiarity with pedagogical practices common to science education, to self-assess their attitudes and competency regarding teaching science in their classroom, and to gauge how supported they felt they were by their administration.

The surveys were sent to all programs participating in the 2016-2017 iGrant but responses within were completely anonymous. Five schools agreed to participate in this study. Out of those schools, six teachers and roughly 100 students were involved. Table 1 presents demographics and assessment information which were collected from the Washington State Report Card for the years 2016-2017 (Office of Superintendent of Public Instruction, n.d.). The school names provided are pseudonyms to protect the anonymity of participating students.

In recent decades, both formal and informal educational facilities have changed how they approach science instruction. The number of partnerships between the two, resulting in blended science programs, has also risen. Formal settings have shied away from the memorization and textbook approach and moved towards more collaborative, hands-on experiences that mimic real-world STEM applications (Bentley et al. 2007; NRC, 1996, 1999, 2007; Yager, 2000). Informal educational facilities have shifted into more community-minded, engaging experiences, often utilizing technology and social media to spread their influence outside of their doors (Gonzalez, 2017; Russo et al., 2006). Both have begun growing partnerships that delve deeper than simple field trips and focus more on long-term collaborations (Bandy & Fung, 2009; Cutucache et al., 2016; Tenenbaum et al., 2015; Urban Advantage, n.d.; Weinstein et al., 2014)

The relationships between student attitude, understanding of content material, and future goals have not been deeply studied, but enough has been researched to show general trends. We can see that students who are engaged in more immersive learning have more positive attitudes towards the STEM content areas and better academic outcomes, though it remains to be seen whether the new standards and practices of the NGSS will radically change student achievement in the sciences (NSB, 2007, 2010; NGSS Lead States, 2013).

Table 1

Demographic and Science Achievement for Participating Schools.

School	School Type	Low Income %	Minority %	% of 5th Graders Passing Science Assessment	% of Teachers with at Least Master's Degree
Rosalind Elementary	Rural	65%	15%	N/A	58%
Meitner Elementary	Suburban	60%	40%	75%	64%
Lovelace Elementary	Urban	90%	60%	60%	64%
Anning Elementary	Rural	80%	10%	70%	40%
Hatathli Elementary	Rural/Tribal	90%	100%	30%	53%

Type of Design and Underlying Assumptions

This study followed survey research design (Mills & Gay, 2016) and focused on quantifiable Likert scale responses. Not only can survey research provide speedy feedback

(Desimone, 2011), but the age and English skills of the participants dictated the necessity of streamlining the collect of data. However, the student surveys also had three open-ended questions designed to clarify and expand student answers from the Likert scale section. To accomplish this for the teachers, the teacher surveys included two open-ended questions.

Turning student opinions and beliefs into interval scale measurements allowed for quantitative analyses. I was able to explore correlations between viewpoints, calculate the means, and determine if differences in those means were statistically significant (Leedy & Ormrod, 2010). This allowed me to explore the different assumptions I had when designing my research questions.

My first assumption was that students who felt they were successful in science, for example students who answered positively on Q5: “I am good at science” or negatively on Q10: “Science is too hard for me,” would be more likely to enjoy science, as shown by positive responses to Q3: “I like using science to solve problems” or Q9: “I enjoy learning science at school.” Next, I assumed that students who showed confidence in their science skills or showed positive attitudes towards it would understand real-world applications to science, Q5: “Science is often used outside of school,” and/or would view science as a possible future career, Q6: “My future job will use science.”

Qualifications and Assumptions of the Researcher

At the time of research, I had spent six years teaching, with four spent working in informal science facilities and two teaching in formal educational facilities, predominantly public elementary schools. I earned a Bachelor of Arts in Education and conducted this research in partial fulfillment of a Master of Education in Curriculum and Instruction. I was employed by a science center as the Education Manager. My responsibilities included program curriculum development, implementation, and outreach. I designed and taught the curriculum for the partnership and was the main point person for contact. Because I trained educators, chose who we worked with, and created museum programming, I hoped this study would guide my future decisions so that I could more effectively increase student attitudes and achievement in STEM content.

As I was an active participant observer (Mills & Gay, 2016) in the study, I knew that my role could have an effect on the students' responses on the survey (Patton, 2001). To mediate this, I was not present when the surveys were administered by the students' regular teachers.

Participants and Sites

The sample set of classrooms selected for these surveys included five sites in four school districts. Originally six sites in five school districts were approached as they matched the following criteria of the partnership; only five chose to be a part of the program. The demographics of each site can be seen in Table 1. Selection was based on the following criteria:

- Must be a public school in Washington state affiliated with the Office of Superintendent of Public Instruction, through which the grant was administered
- Must be within the science center's area of service in Eastern Washington
- Must serve students in grades 3-5
- Must have a high (defined as over 60%) percentage of low-income students
- Must accept partnership with the science center under the iGrant's goals for 2015-2016

Data Collection

Surveys were mailed out to each site in packets containing fifty blank student surveys and one blank teacher survey. The student surveys consisted of ten Likert scale questions and three open-ended questions on student attitudes and practices in STEM while the teacher surveys consisted of twenty-six open-ended and five Likert scale questions about instructional practices and professional qualifications. To protect the anonymity of minors, surveys included no identifying markers and were mailed back in pre-addressed envelopes to the science center.

Each packet contained a Letter to Parents (Appendix C) and an overview of the study and the minor consent form for the students' guardians to fill out and return with the finished surveys (Appendix A). The teachers also received the Letter to Teachers (Appendix D), which was very similar to the Letter to Parents and also contained the teacher consent form to participate in the study. Finally, the packet included a copy of the Teacher Survey (Appendix B).

In addition to mailing out physical surveys and guides, I emailed each site digital copies and a timeline for when to send the materials back. I also sent out a reminder email to every site about a week before the deadline.

Data Analysis

The returned surveys were randomly assigned a number to further protect the anonymity of the student participants. They were then entered into Excel sheets and the Likert responses turned into corresponding numbers, thus Strongly Disagree became 1, Disagree became 2, Agree became 3, and Strongly Agree became 4. SPSS software was used to run quantitative analyses. Descriptive statistics were analyzed to examine the basic features of the data and make them more manageable (Graveteer & Wallnau, 2004). Then, the relationship between responses were measured using the Pearson r correlation (Morgan, Leech, Gloeckner, and Barrett, 2004).

Conclusion

Following survey research design found in the literature (Mills & Gay, 2016), the surveys were designed to answer the three research questions regarding participation in blended informal-formal science educational programs and their effect on student attitudes and achievement in conceptual understanding of science content. Due to insufficient participation from teachers, the teacher survey was not included in this data analysis as I did not feel that two responses out of six was sufficiently representative of the participants. In all but one returned set, the teacher survey was not returned so students and teachers could not be matched; the second teacher survey was dropped off at the museum anonymously. I received four sets of student data back, leading me to believe that four out of five schools are represented in the data. Out of just over 100 student participants, 80 student surveys were returned; two were not included as the survey was filled out incorrectly and answers could not be accurately measured. However, the N=78 student survey Likert responses were converted into interval scale measurements so quantitative analysis could be run. After running the data through SPSS software, descriptive statistics were analyzed to determine the means of each question and determine the statistical significance of each mean (Graveteer & Wallnau, 2004; Leedy & Ormrod, 2010). Finally, the relationship between the responses specifically relating to each research question were measured using a Bivariate Pearson *r* correlation (Morgan, Leech, Gloeckner, & Barrett, 2004). These results are presented in Chapter 4 Findings and discussed in detail in Chapter 5 Conclusions and Reflections.

CHAPTER 4

Findings

Introduction

This chapter explores the data analysis and results of the 78 student surveys (Appendix A) taken by 2016-2017 iGrant partnership participants in 4th and 5th grade. The purpose of this research was to investigate three questions:

1. How have these formal and informal educational institutions approached science instruction historically compared to now?
2. How do blended educational experiences involving both informal and formal facilities affect student attitudes towards science?
3. How does a student's grasp of science content relate to their attitudes and future goals in science learning?

Through the use of survey data, I explored the relationship between attitudes towards STEM, confidence in STEM content mastery, and future goals of students. I hoped to see growth in students involved in a collaborative learning program between public elementary schools and an informal science museum. I hoped to find a relationship between positive student attitudes towards science and student confidence and future goals relating to STEM. Drawing upon my experience and review of the literature, I assumed that students who could connect STEM content to their out-of-school experiences would have both higher achievement and more positive attitudes towards it. Based on prior partnerships, I assumed that teachers with more experience and school support would not only be more familiar with different practices, but more willing to try partnerships with informal institutions. My professional experience had provided me with a good set of anecdotes to draw on to support this while the literature served to confirm much of what I had witnessed firsthand; I assumed I would see this reflected within the data I collected from the participants in the blended science partnership. Unfortunately, due to delays in IRB approval and the lack of flexibility in the program start date, only post surveys could be collected for analysis. This limited the analyses that could be run and the possible conclusions.

While six different formal educational classrooms met the program criteria and were approached, only five agreed to participate in this study. Hatathli Elementary only requested one visit, while the other sites each had three to four different lesson activities. This did not change their survey questions. The data was collected through anonymous surveys sent at the end of the 2016-2017 school year, after the completion of the partnership. To ensure anonymity, a package containing fifty student surveys (Appendix A), one teacher survey (Appendix B), survey guides and overviews (Appendices C and D), and a pre-marked return envelope were sent to each site after the program's end a month before the school year ended. The student surveys consisted of ten quantifiable questions focused on attitudes and beliefs towards STEM and arranged in a four-point Likert scale consisting of Strongly Disagree, Disagree, Agree, and Strongly Agree. The surveys also asked three open-ended questions about science activities in and out of school that students knew about or enjoyed participating in.

The teacher survey focused on individual usage and familiarity with varying pedagogical practices, 14 questions about their beliefs and attitudes towards science instruction and support on a four-point Likert scale. This survey also had two open-ended questions on important issues in modern science learning. Unfortunately, as only two of the six teachers returned surveys with their student data, the decision was made to remove the teacher surveys from the analysis as I did not feel two were sufficiently representative of the participating teachers' views.

Data and Data Analysis

The post-program student surveys (N=78) were collected and prepared for analysis. Roughly 100 students participated in the program and 80 student surveys from four sites were returned. However, two students did not accurately fill out the Likert scale and their answers could not be conclusively determined; these two surveys were not included in the analysis. Not having access to the pre-program surveys limited the analyses that could be conducted. Fortunately, correlational analysis could be completed – this was done after examining the descriptive patterns in the data.

Descriptive Statistics

Descriptive statistics were run using SPSS software. These results are displayed in Table 2. It is interesting that the question with the highest mean, Q4, “My science teacher asks us to explain our thinking,” was also one of the two questions with the lowest N. Yet, it is not possible to explain why students skipped this question.

The descriptive statistics revealed other interesting patterns. For instance, every single question produced a range of 3, telling us that each question had varied responses with at least one student picking each response. Comparing the histograms also revealed patterns. Q3: “I like using science to solve problems” and Q7: “I am good at science” had nearly identical means, even though Q7 had noticeably more “Agree” responses (Figure 1). Figure 2 shows how Q1: “When I work with other students on a science problem, we help each other figure out the answers” and Q8: “Science helps me answer my questions about the world” had the exact same mean yet differed substantially in how their responses were divvied out.

Table 2

Descriptive Statistics

Question	N	Range	Mean	Std. Deviation
Q1	76	3	3.09	-.872
Q2	76	3	1.88	.610
Q3	77	3	2.92	-.430
Q4	74	3	3.61	-1.726
Q5	78	3	2.64	-.145
Q6	76	3	2.17	.562
Q7	78	3	2.97	-.658
Q8	76	3	3.09	-.369
Q9	74	3	3.30	-1.125
Q10	76	3	1.72	.997

Bivariate Correlations

Bivariate Pearson *r* correlational analysis was run using SPSS software. The results of this analysis are presented in Table 3. Certain correlations might be expected because of logical relationships in the questions. For example, when looking for student attitude I looked to Q3: “I like using science to solve problems” and Q9: “I enjoy learning science at school.” For ability confidence, I used Q7: “I am good at science” for a positive correlation and Q10: “Science is too hard for me” for a negative correlation. However, the correlations for these combinations were very low and statistically insignificant:

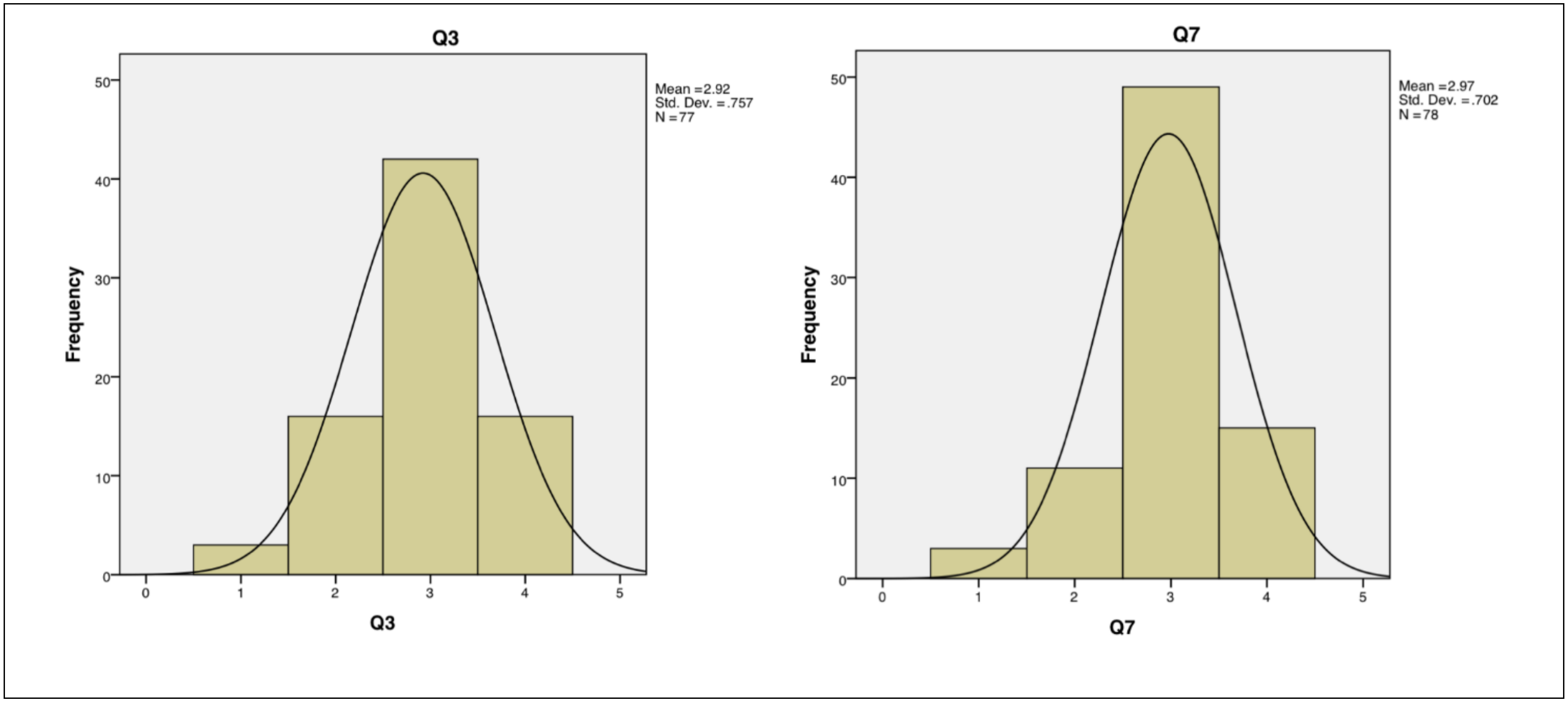

Figure 1. Histograms for Q3, “I like using science to solve problems” and Q7, “I am good at science.”

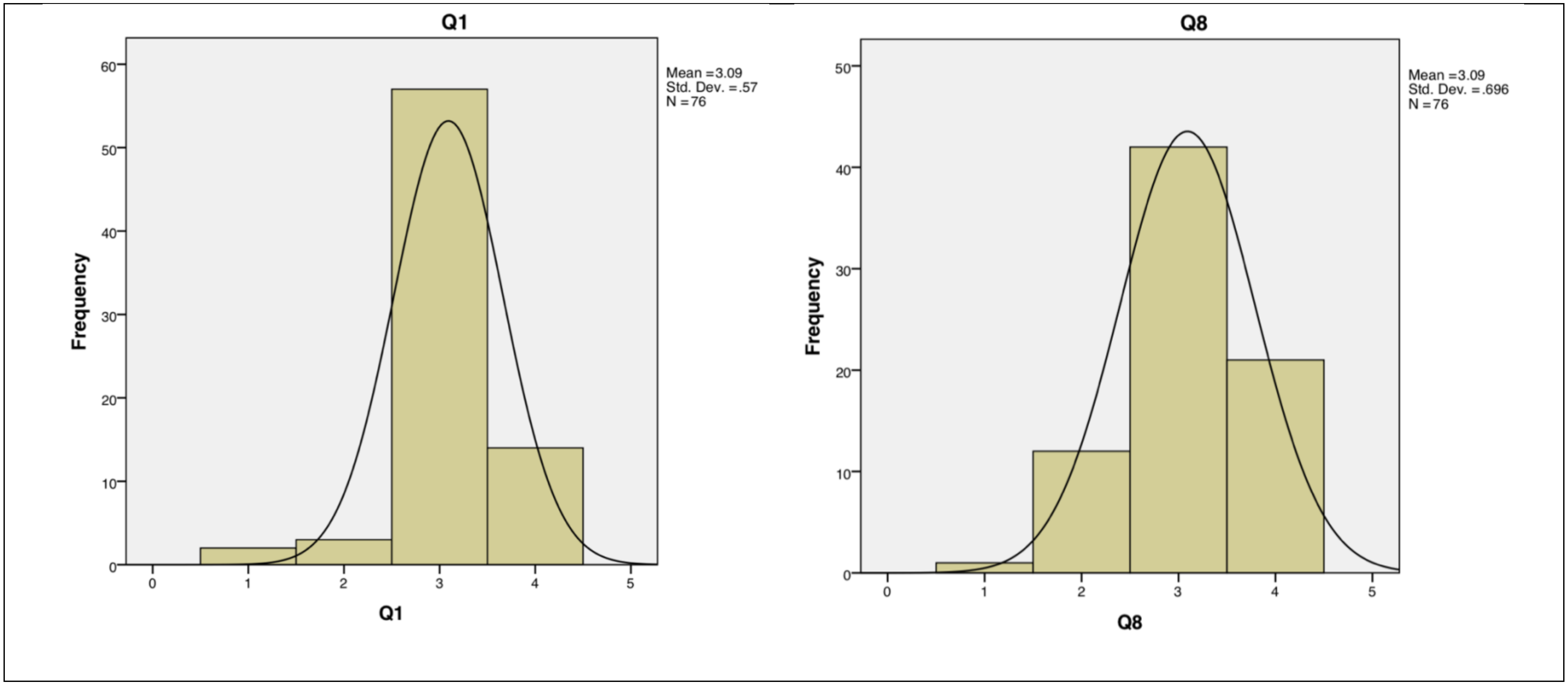

Figure 2. Histograms for Q1, "When I work with other students on a science problem, we help each other figure out the answers" and Q8, "Science helps me answer my questions about the world."

- Q3 and Q7: 14.4%
- Q3 and Q10: -2.1%
- Q9 and Q7: 18.2%
- Q9 and Q10: -9.5%

To see if students may be interested in pursuing a future STEM career, I used Q6: "My future job will use science." Yet again, the correlations were surprisingly lacking using both attitude and perceived aptitude:

- Q3 and Q6: 10.3%
- Q9 and Q6: 14.9%
- Q7 and Q6: 19.5%
- Q10 and Q6: -17.6%

While not following patterns that may be logically assumed, they did reveal other interesting observations. There was a statistically significant ($p = 0.024$) negative correlation of -.259 between a student's grade level and their response to Q10: "Science is too hard for me," showing that older students were less likely to feel that science is too difficult. Q3: "I like using science to solve problems" and Q8: "Science helps me answer my questions about the world" had a statistically significant ($p= 0.002$) positive correlation of .348. It is reasonable that students who enjoy solving problems using science would also enjoy using it when questioning the world around them. Q3: "I like using science to solve problems" was also positively correlated to Q9: "I enjoy learning science at school" and statistically significant ($p= 0.011$). Again, it is not surprising that students who enjoy learning science would also enjoy employing it to solve problems at hand. Finally, Q7: "I am good at science" had the strongest correlation with Q10: "Science is too hard for me." This negative correlation was also statistically significant

($p = 0.000$). Students who feel they are good at science are unlikely to think it is too difficult, so this correlation rings true.

Table 3

Bivariate Pearson r Correlations

		Grade	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10
Grade												
	Pearson Correlation	1	.144	-.049	.095	-.038	.160	.014	.019	.071	.010	-.259*
	Sig. (2-tailed)		.214	.673	.413	.749	.163	.904	.871	.541	.930	.024
	N	80	76	76	77	74	78	76	78	76	74	76
Q1	Pearson Correlation	.144	1	.098	-.017	-.077	.149	.085	-.163	.082	.060	-.078
	Sig. (2-tailed)	.214		.407	.888	.518	.199	.473	.160	.487	.617	.512
	N	76	76	74	75	72	76	74	76	74	72	74
Q2	Pearson Correlation	-.049	.098	1	.011	-.140	-.176	.041	-.166	-.080	.224	.173
	Sig. (2-tailed)	.673	.407		.923	.238	.128	.731	.153	.497	.057	.141
	N	76	74	76	75	73	76	74	76	75	73	74
Q3	Pearson Correlation	.095	-.017	.011	1	.141	.060	.103	.144	.348**	.298*	-.021
	Sig. (2-tailed)	.413	.888	.923		.233	.601	.378	.212	.002	.011	.861
	N	77	75	75	77	73	77	75	77	.075	73	75
Q4	Pearson Correlation	-.038	-.077	-.140	.141	1	.164	-.228	-.023	.166	.151	-.086
	Sig. (2-tailed)	.749	.518	.238	.233		.161	.054	.843	.159	.207	.468
	N	74	72	73	73	74	74	72	74	73	71	73

		Grade	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10
Q5	Pearson Correlation	.160	.149	-.176	.060	.164	1	-.002	.133	.061	.093	-.191
	Sig. (2-tailed)	.163	.199	.128	.601	.161		.984	.245	.601	.429	.099
	N	78	76	76	77	74	78	76	78	76	74	76
Q6	Pearson Correlation	.014	.085	.041	.103	-.228	-.002	1	.195	.015	.149	-.176
	Sig. (2-tailed)	.904	.473	.731	.378	.054	.984		.091	.902	.211	.134
	N	76	74	74	75	72	76	76	76	74	72	74
Q7	Pearson Correlation	.019	-.163	-.166	.144	-.023	.133	.195	1	-.079	.182	-.548**
	Sig. (2-tailed)	.871	.160	.153	.212	.843	.245	.091		.496	.121	.000
	N	78	76	76	77	74	78	76	78	76	74	.76
Q8	Pearson Correlation	.071	.082	-.080	.348*	.166	.061	.015	-.079	1	.050	-.053
	Sig. (2-tailed)	.541	.487	.497	.002	.159	.601	.902	.496		.674	.654
	N	76	74	75	75	73	76	74	76	76	74	74
Q9	Pearson Correlation	.010	.060	.224	.298*	.151	-.093	.149	.182	.050	1	-.095
	Sig. (2-tailed)	.930	.617	057	.011	.207	.429	.211	.121	.674		.425
	N	74	72	73	73	71	74	72	74	74	74	72
Q10	Pearson Correlation	-.259*	-.078	.173	-.021	-.086	-.191	-.176	-.548**	-.053	-.095	1
	Sig. (2-tailed)	.024	.512	.141	.861	.468	.099	.134	.000	.654	.425	
	N	76	74	74	75	73	76	74	76	74	72	76

*. Correlation is significant at the 0.05 level (2-tailed).

**. Correlation is significant at the 0.01 level (2-tailed).

CHAPTER 5

Conclusions and Reflections

Introduction

The history of science education in the United States is one of constant change. With the NGSS being implemented and sweeping reform being undertaken by districts across the country, it remains unclear whether this will usher in a new era of enhanced science literacy and attitudes, or if this will be yet another set of standards and pedagogies that is shifted aside after a few years (Achieve et al., 2013; NSB, 2010). One possible way to promote success is for formal science facilities, like public schools, to partner with informal science facilities in their communities. While research into the efficacy of their partnerships is nascent, there are indicators that show an opportunity to increase both academic growth and build positive attitudes towards science for students through the utilization of long-term community partnerships between the two types of educational facilities (Cutucache et al., 2016; Bandy & Fung, 2009; Urban Advantage, n.d.; Weinstein et al., 2014).

The purpose of this study was to put the current pedagogical shifts into context by comparing them to their historical precedents, exploring previous and current community partnerships between informal and formal science institutions, then investigate how those blended science education experiences affect student attitudes towards science, and finally to see if predictions can be made of future goals and attitudes towards science based on a student's science literacy.

This study is the result of a year-long partnership between an informal science center and five formal science programs within public elementary schools. The science center designed Earth science courses based on the geographical history unique to the local area and students participated in these activities both at the science center as field trips and within their own classrooms. At the end of the program, both teachers and students were given anonymous surveys designed to assess pedagogical practices within the classroom, teacher experience in partnerships with informal science facilities outside of the grant, attitudes towards science, self-assessment on scientific literacy levels, and how supported teachers felt in their science instruction.

These topics were chosen based on themes frequently presented in the literature review. The themes were (1) Science Pedagogical Practices, (2) Informal-Formal Science Partnerships, (3) Science Programs and Student Attitude Towards STEM, (4) Student Achievement in and Attitude Towards STEM, and (5) Long-term Effects of Science Programs on Students. Themes 1 and 2 are the answer to the first research question; 3 answers the second research question; themes 4 and 5 explore the third research question. Student attitude was measured based on the 4C Model by Clevenger (1995), which assesses students based on curiosity, competence, confidence, and courage. Later in unpublished work, she added "collaboration" and changed the name to the 5C Model (Clevenger, 2016).

To assess these topics, both quantitative and qualitative data was collected. The student survey (Appendix A) contained ten Likert scale questions and three open-ended questions organized around their attitudes and usage of STEM both in and out of the classroom. The teacher survey (Appendix B) had nineteen Likert scale questions on their familiarity with common science pedagogical practices, their attitudes towards science and science instruction, and their level of support in teaching science. This survey also included open-ended written response questions diving deeper into their pedagogical practices, their experience teaching, and current issues they felt were important in science instruction. Likert scale responses and short written responses were chosen both for the ease of quick feedback (Desimone, 2011) and to streamline data collection based on the young age and elementary English skills of the participants. This approach is known as survey design (Mills & Gay, 2016).

As only a third of the teachers returned surveys, I did not include their survey responses in this paper as I did not feel confident in drawing conclusions from the small sample. However, 80 student surveys, out of roughly 100 student participants, were returned and prepared for analysis. Originally, the open-ended written responses were to be coded to track trends in student curiosity and to see if students who agreed with Q5, "Science is often used outside of school" could list examples to back their answer up. However, likely due to the students' young age and less-advanced English skills, the responses were often too illegible to analyze accurately and there were not enough clear responses to accurately explore any relationships. Two student surveys answered "yes" or "no" in different boxes on their Likert responses and so were not included in the analyses as it was unclear what their responses were trying to convey, leaving an $N=78$. Any question responses which included more than one answer, in addition to questions that were left blank, were also removed from the sample. After turning the Likert scale responses into interval scale measurements to allow for quantitative analyses, I was able to investigate descriptive statistics and correlations (Leedy & Ormrod, 2010). Descriptive statistics were run using SPSS software and can be found in Table 2. Bivariate Pearson r correlational analysis was also run using SPSS software and the results are provided in Table 3.

Conclusions

The surveys were designed to explore any possible relationships between attitudes towards STEM, the future goals of students relating to science, and their confidence in STEM content mastery. I expected to find that students who participated in a blended informal and formal science program would show growth in their scientific literacy and that they would also show a positive correlation between their attitudes towards STEM and both their confidence levels and intention to utilize science in a future career. However, issues with IRB approval and an inflexible start date in the program led to only post surveys being collected for analysis. Therefore, the analyses that could be run and possible conclusions were limited.

Descriptive statistics were run using SPSS software and are displayed in Table 2. One of the more interesting items of note was that Q4, “My science teacher asks us to explain our thinking,” had the highest mean at 3.61 yet it also had the lowest N. Why did some students choose to not respond to this prompt? It is possible that they felt uncomfortable in answering such a question about their teacher—not confident that their answers would really be anonymous. This is the very reason I avoided being present for the survey completion, following Patton’s (2001) reminder of the unintended influences of participant researchers. Unfortunately, this could also have influenced the high mean score on this question as well.

To connect Theme (1) Science Pedagogical Practices to my research, the teacher survey asked teachers to both rate their familiarity with common practices and to note whether or not they used it in their classroom. The pedagogical practices or standards were inquiry-based learning, problem-based learning, the 5E Instructional Model, the NGSS, and informal science programs. Due to the statistically insignificant teacher response for surveys, however, I could not connect the practices used in the classrooms of participating teachers with practices utilized in the literature.

Within the student surveys, I did include several questions that looked towards the pedagogical practices students were participating in, though there is not enough detailed information to accurately predict which approach their teacher most frequently employs. The first question was Q1, “When I work with other students on a science problem, we help each other figure out the answers.” The NRC (2007) argues for collaboration within learning that includes working together to solve issues, instead of the more traditional argument style which is more focused on winning or a black and white sense of right or wrong. To do this, students must have the opportunity to work together during science lessons (Bentley et al., 2007). For this question, the mean was 3.09, showing that the majority of students agreed that a collaborative model was used in their classroom.

To further explore this, I asked two contrasting questions relating to the constructivist model “instead of on direct memorization of facts and methods” (Konicek-Moran & Keeley, 2015, p. 88). The first was Q2: “Science is just memorizing facts,” and Q4: “My science teacher asks us to explain our thinking.” For Q2 the mean was 1.88, showing that most students disagreed that science was just memorizing facts. It then follows that Q4: “My science teacher asks us to explain our thinking” would show that students feel they do more than just memorize things, and students mostly agree, with a mean of 3.61, that they explain their thinking during science lessons. However, when these questions are compared through the Bivariate Pearson *r* correlational analysis, there were no statistically significant predictors, as seen in Table 2. From this we cannot conclude there is a relationship between these questions nor make predictions as to the actual pedagogical practices found in the students’ classrooms. The histograms for these questions are compared in Figure 3.

For Theme (2) Informal-Formal Science Partnerships, I had intended to explore two questions on the teacher survey. I asked teachers to rate their familiarity with informal science and ask if they had used outside groups, such as museums, in their science instruction, previous to the partnership they were currently participating in. Due to a lack of teacher data to analyze, this theme could not be explored in my research analysis.

Theme (3) Science Programs and Student Attitude was to be analyzed by comparing a pre- and post-survey of the participating students to see if the blended informal-formal program would have any effect on their attitudes towards science. My assumption was that students would see an uptick in positive attitudes after completing the program. One of the six strands of science learning for informal science programs, as laid out by the NRC (2009), was an increase in excitement, interest, and motivation when compared to formal science instruction. Additional studies found in the literature also showed an increase in attitude for those who participated in informal science learning and I reasoned that participation in this would lead to similar results (Bamberger & Tai, 2008; Csikszentmihalyi & Hermanson, 1995; Cutucache et al., 2016; Knapp, 2000; NRC, 2009; Sacco et al., 2014; Salmi, 2003; Suter, 2014). I could not investigate potential changes over time in student attitudes due to IRB delays preventing data collection until the end of the program though, so I was not able to compare my results with the literature's results.

The student survey did have three questions that looked at attitudes towards science. The first was Q3, "I like using science to solve problems," the second was Q8, "Science helps me answer my questions about the world," and finally Q9, "I enjoy learning science at school." Table 1 shows Q3 with a mean of 2.92. The histogram in Figure 3 shows us that a strong majority of students agree with this statement, an equal amount disagree or strongly agree, and so the small number who strongly disagree bring the mean down slightly.

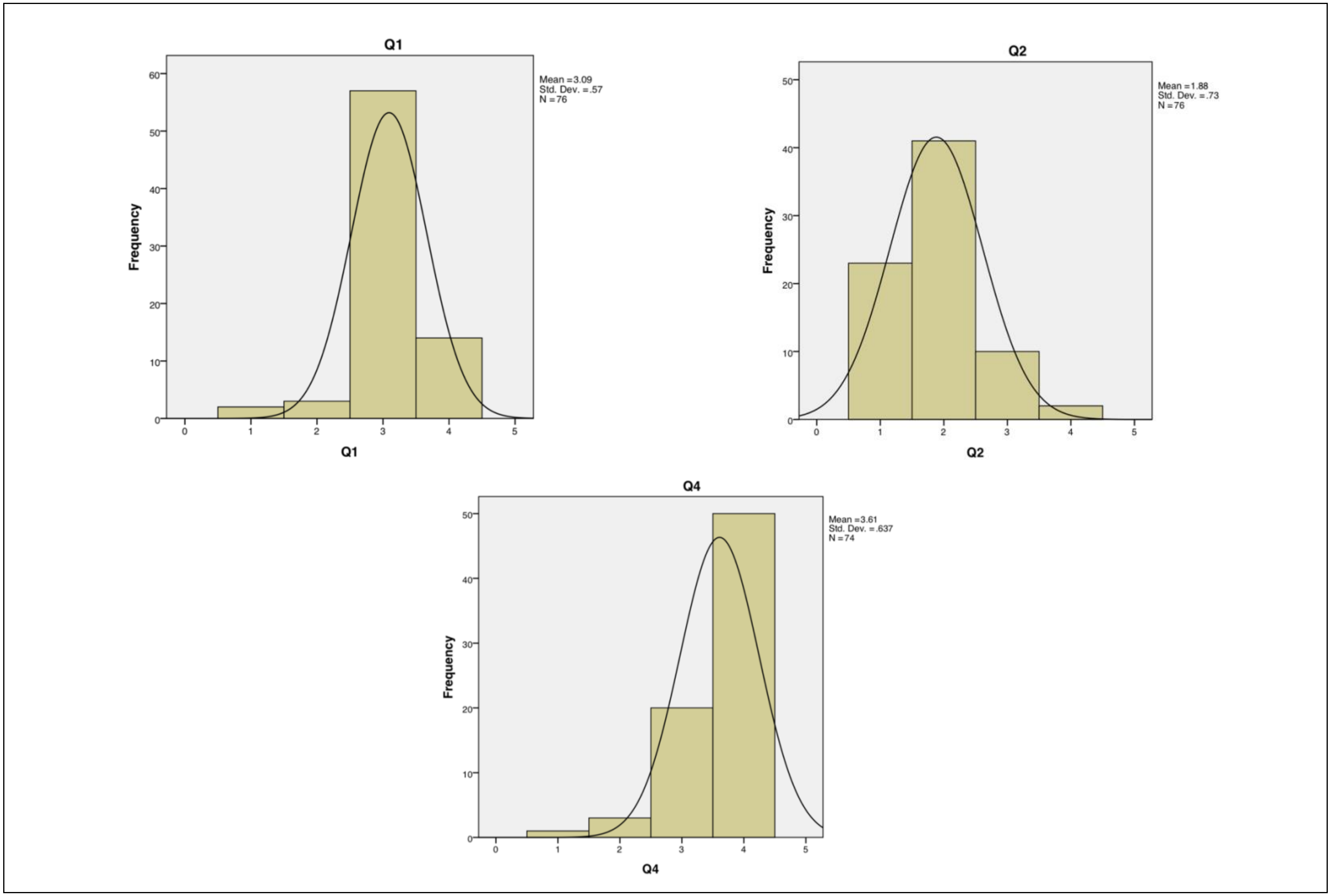

Figure 3. Histograms for Q1, “When I work with other students on a science problem, we help each other figure out the answers,” Q2, “Science is mostly just memorizing facts,” and Q4, “My science teacher asks us to explain our thinking”

The mean for Q8: "Science helps me answer my questions about the world" was 3.09, with noticeably more students agreeing. In Q9: "I enjoy learning science at school" the mean is slightly misleading. While the mean is 3.30, 34 students each either agree or strongly agree with the statement, nearly 92% of the students. My research showed a statistically significant positive correlation between Q3: "I like using science to solve problems" and Q8: "Science helps me answer my questions about the world," which I had assumed. I believed that students who enjoyed using science to solve problems would both be more interested in using science to answer their own curiosity and there is enough data to find a relationship between the two. There was also a positive correlation between Q3: "I like using science to solve problems" and Q9: "I enjoy learning science at school" between the two questions of .298. It is reasonable to conclude from this data that students who like using science for problem-solving are more likely to enjoy using it to tackle various activities they would encounter during a typical science class. However, there was no significant correlation between Q8: "Science helps me answer my questions about the world" and Q9: "I enjoy learning science at school."

For Theme (4) Student Achievement in and Attitude Towards STEM, my inquiry was into whether or not students who rated themselves as capable in STEM would have more positive attitudes towards it. My assumption was that the confidence in skills mastery would make students more likely to enjoy practicing and deepening those skills. Suter (2014) showed that high school students more interested in science thus took more courses over the next four years. The students who showed the highest interest, measured by four or more classes, achieved over 20% higher science scores on assessments than students who took no additional classes. His research showed that each additional class raised student achievement scores by about 5%.

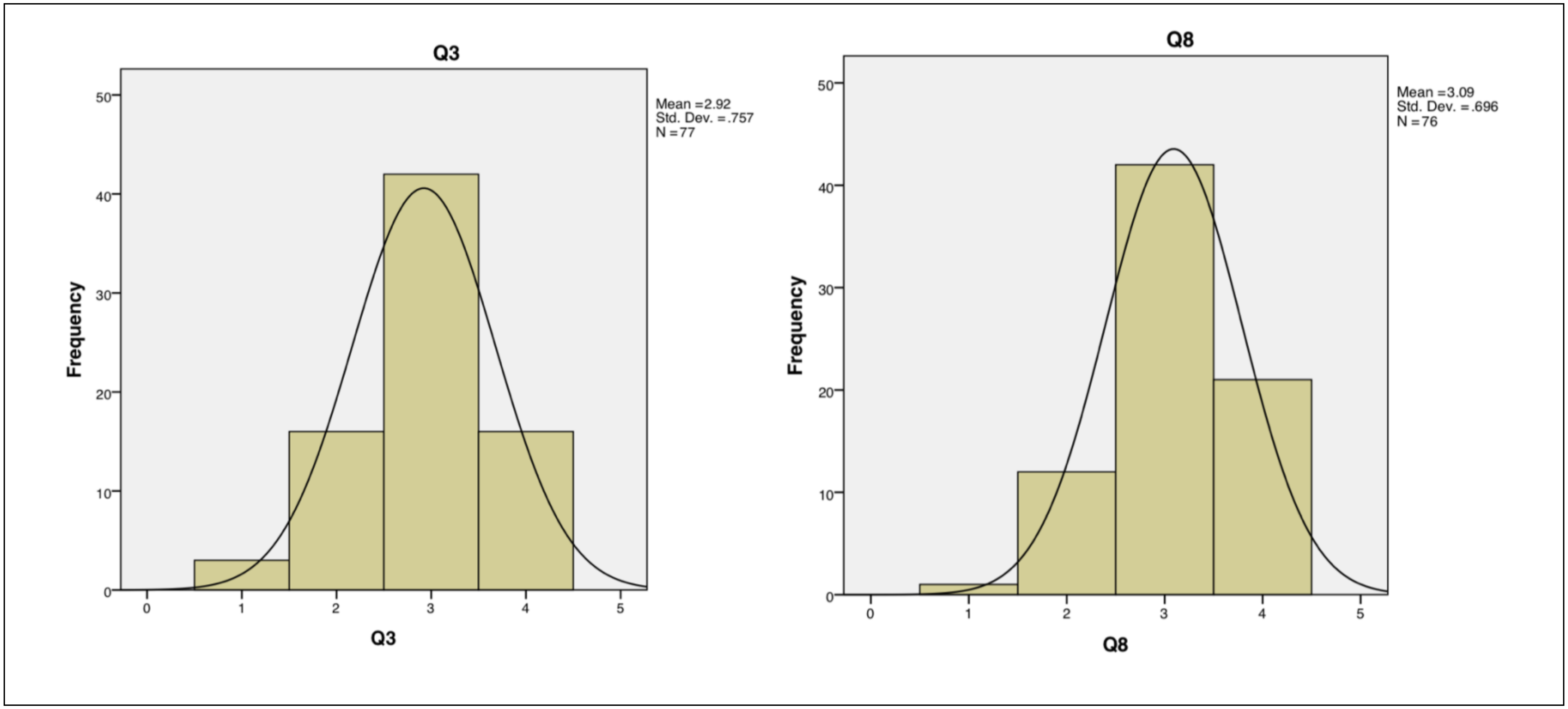

Figure 4. Histograms for Q3, "I like using science to solve problems" and Q8, "Science helps me answer my questions about the world"

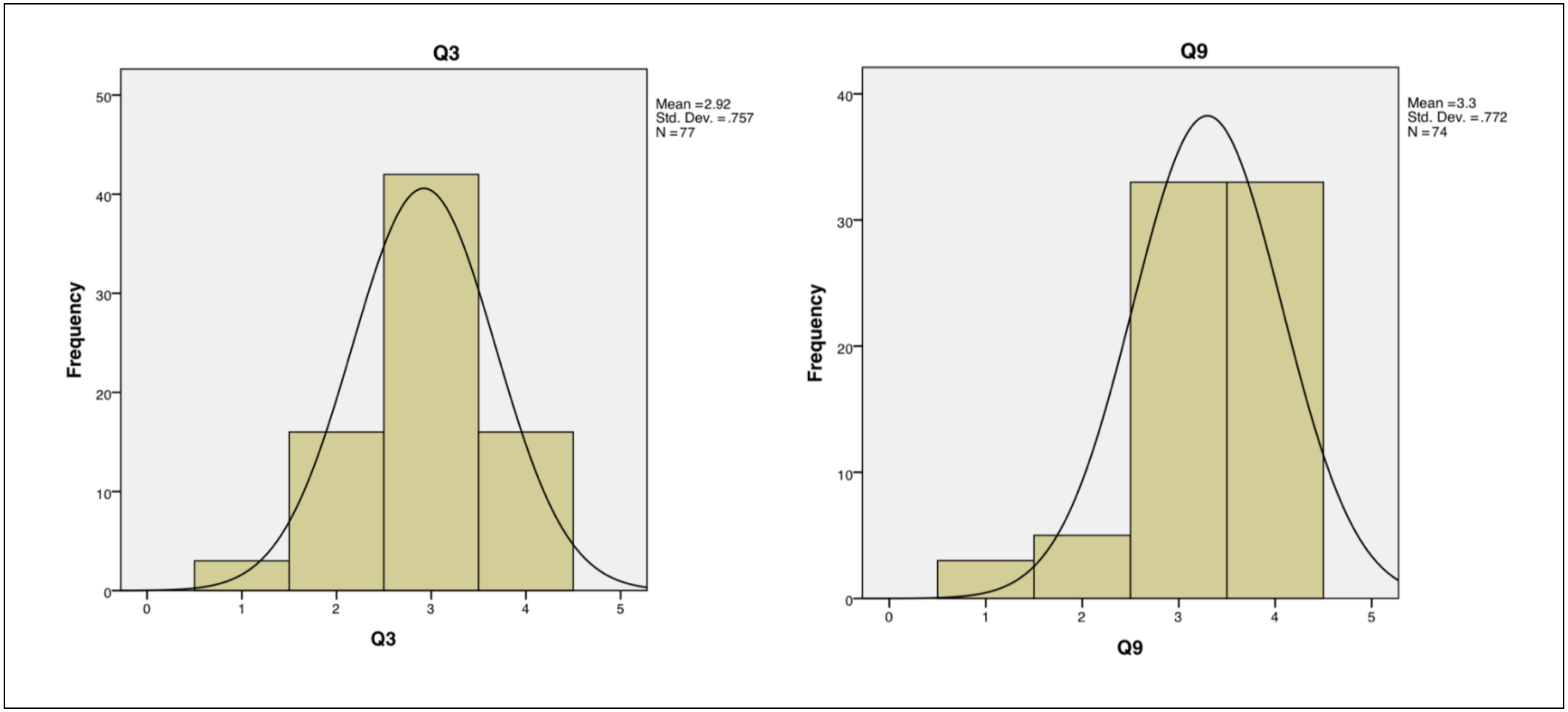

Figure 5. Histograms for Q3, "I like using science to solve problems" and Q9, "I enjoy learning science at school"

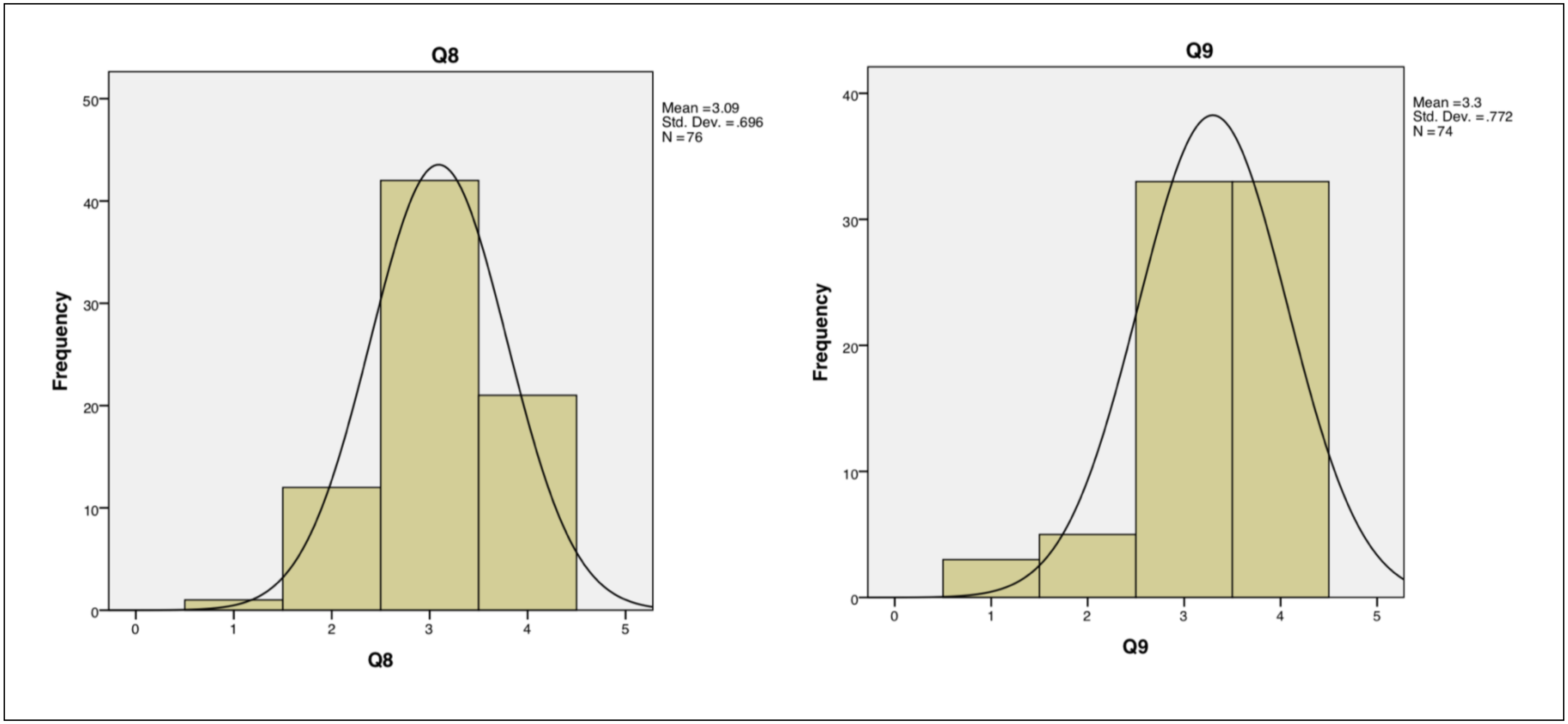

Figure 6. Histograms for Q8, “Science helps me answer my questions about the world” and Q9, “I enjoy learning science at school”

Csikszentmihalyi and Hermanson (1995, p. 68) show that "students who are intrinsically motivated tend to have higher achievement scores…and they develop their aptitudes further over time."

To examine this theme, I compared the previous attitude questions, Q3: "I like using science to solve problems" and Q9: "I enjoy learning science at school," each to Q7, "I am good at science" and Q10, "Science is too hard for me." As I could not examine actual student achievement scores, I focused on self-perception of skills. As I had predicted when I designed the survey, there was a strong negative correlation between Q7: "I am good at science" and Q10: "Science is too hard for me" at -.548, as seen in Figure 7. Thus, we can conclude that the more confident a student feels when practicing science, the less challenging they will view it. Heaverlo (2011) found a similar positive correlation between science interest and confidence in young women in grades 6-12. Interestingly, in Gormally et al. (2009), in a study comparing the achievement and confidence growth between two cohorts of university undergraduates taking either a traditionally formatted course or an inquiry-based course, they found that students in the inquiry-based program gained confidence, but at a lower rate than the traditional control group. However, the inquiry-based program students scored higher on a post-test assessment across both semesters this study was conducted. The literature supports the idea that there may be more variables at play than a simple positive correlation between attitude and achievement (Gormally et al., 2009; Heaverlo, 2011).

When I compared Q3: "I like using science to solve problems" to Q7: "I am good at science" (Figure 8) and Q3: "I like using science to solve problems" to Q10: "Science is too hard for me" (Figure 9) I found no statistically significant correlations with there being almost no correlation at all between Q3 and Q10 ($p = -.021$).

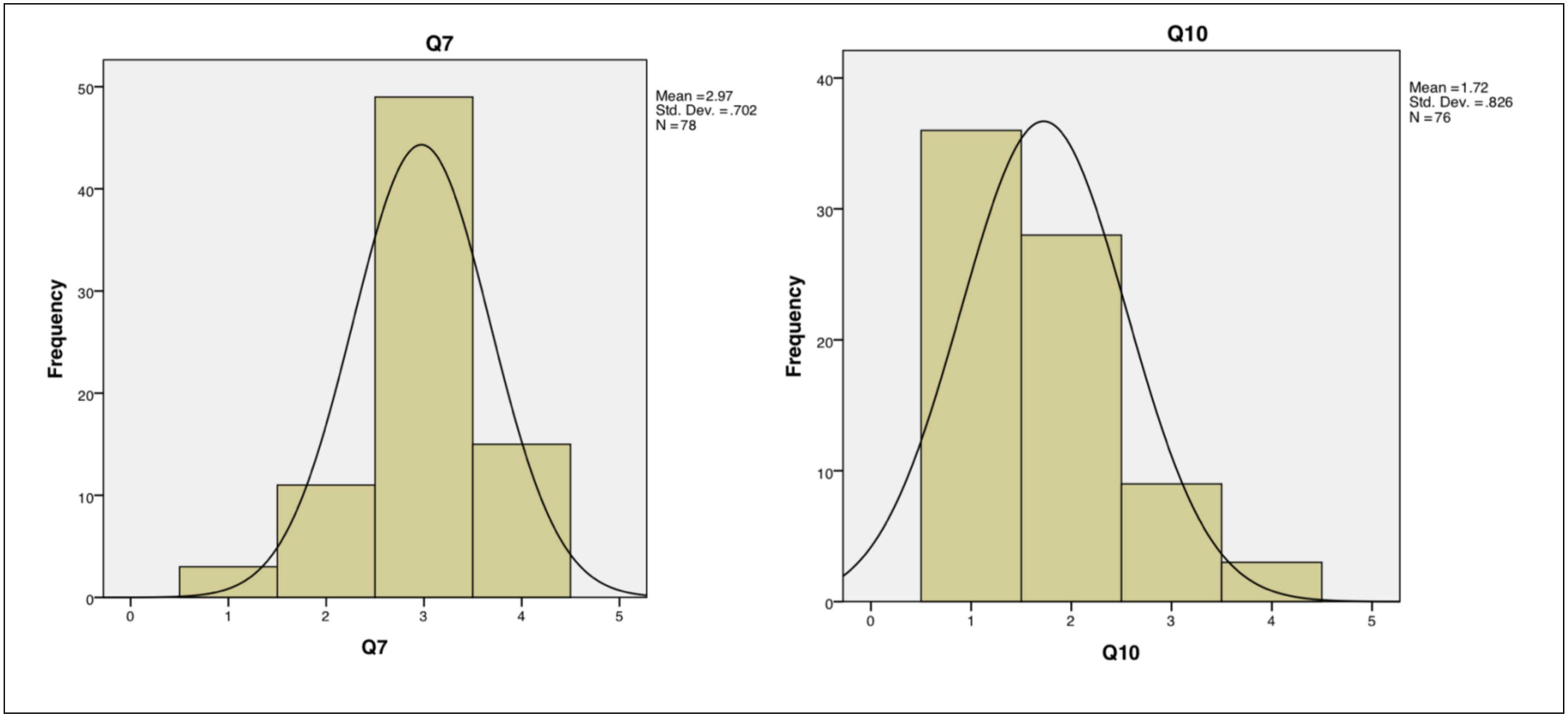

Figure 7. Histograms for Q7, “I am good at science” and Q10, “Science is too hard for me”

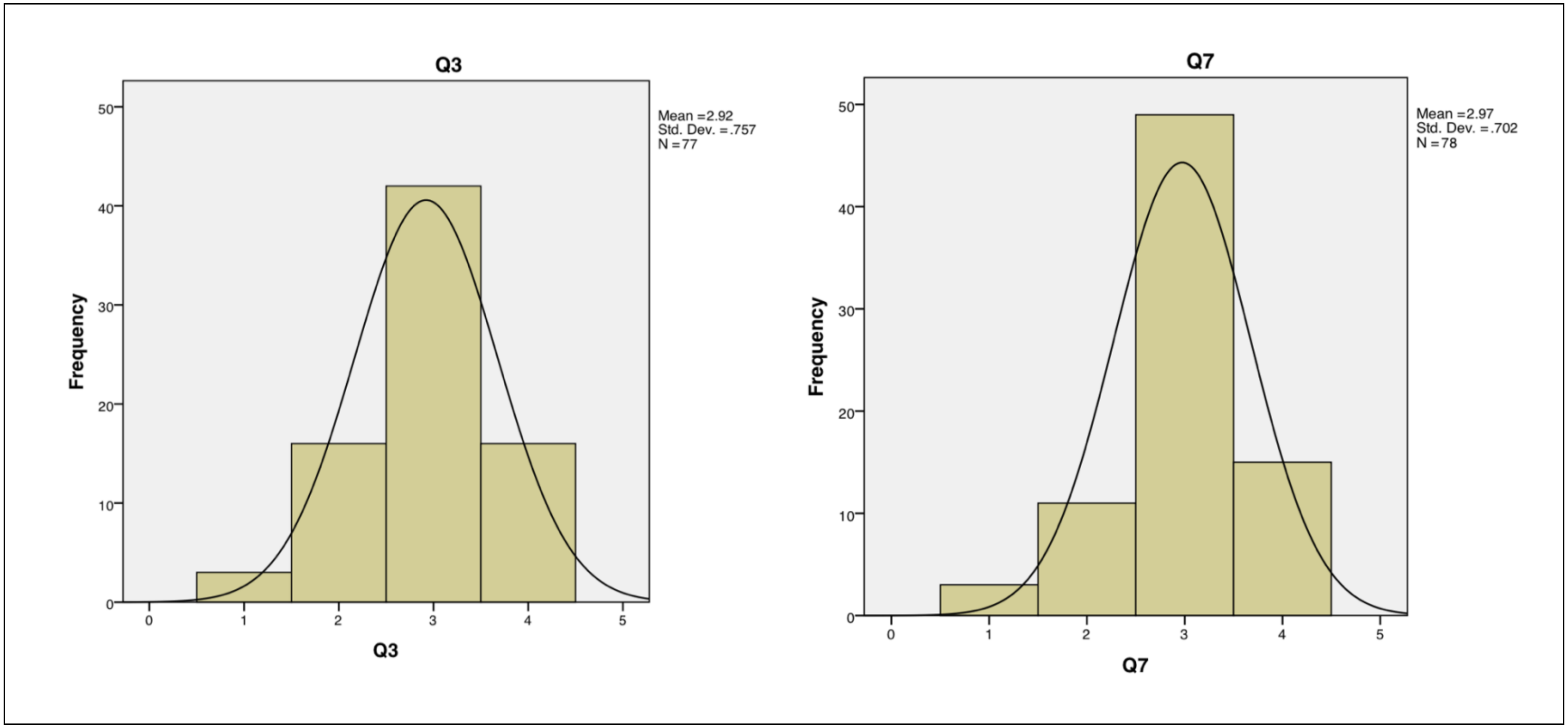

Figure 8. Histograms for Q3, "I like using science to solve problems" and Q7, "I am good at science"

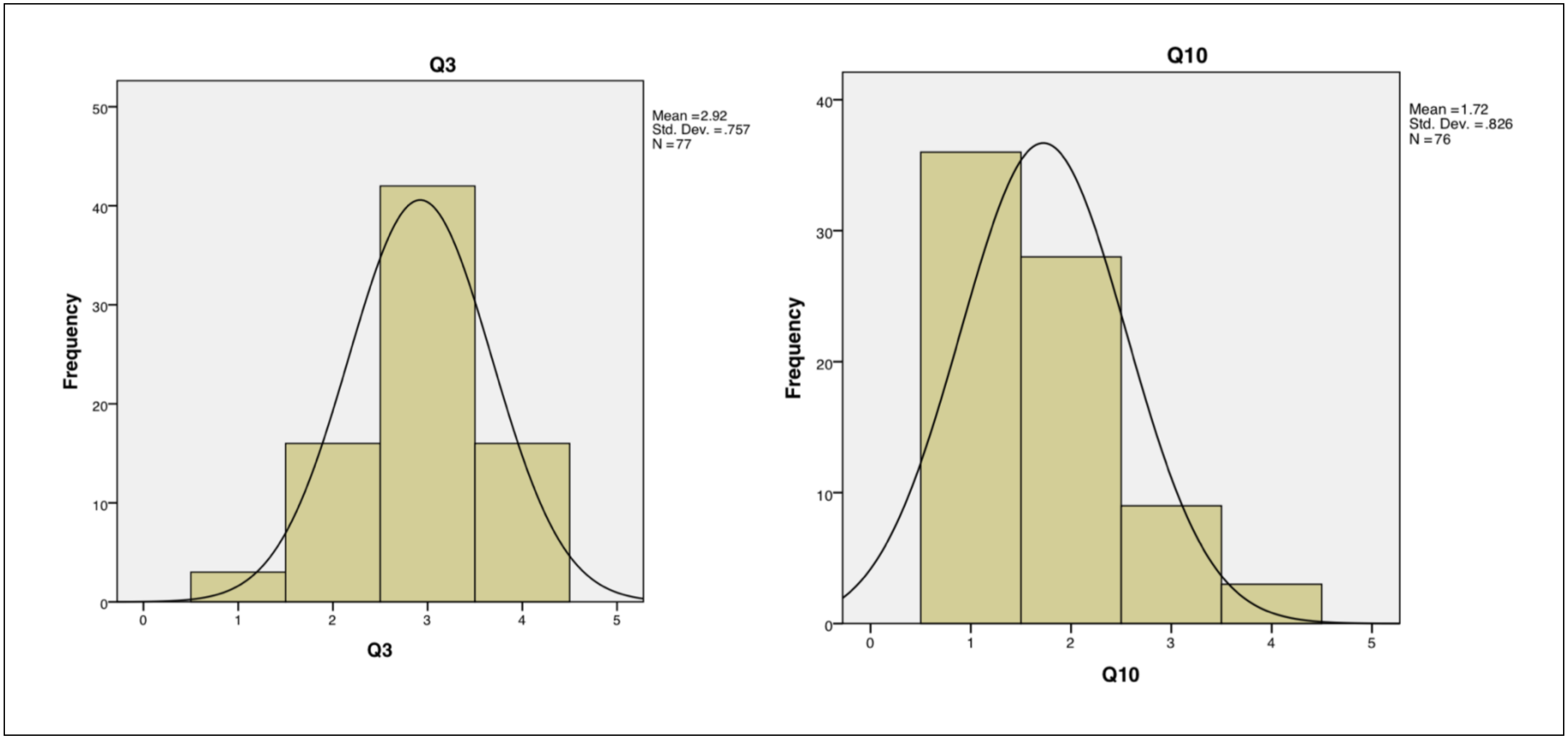

Figure 9. Histograms for Q3, "I like using science to solve problems" and Q10, "Science is too hard for me"

Similarly, I found no statistically significant correlations between Q9: “I enjoy learning science at school” and Q7: “I am good at science” (Figure 10) or Q9 and Q10: Science is too hard for me” (Figure 11), again with Q10 providing the weakest connection. I could neither support nor disprove the idea that there is a relationship between attitude and achievement, as my research was inconclusive either way.

Finally, I hoped my surveys could explore the long-term effects of these science programs on students. Two studies found that visits to informal science facilities were still impacting students sixteen months (Bamberger & Tai, 2008) or even eighteen months (Knapp, 2000) later, with students still able to recall important content and experiences and felt that it had been a worthwhile and valuable activity. Salmi (2003) found that museum trips could influence students even further out and go so far as to inspire students to choose science fields for their careers. I had hoped to compare pre- and post-survey results to see the potential growth students experienced while participating in the blended informal-formal experience and to see if students would be more interested in a science career after the program, but I was not able to collect such data. However, I was still curious if there would be a relationship between Q5: “Science is often used outside of school” and Q6: “My future job will use science” (Figure 12). My assumption was that students who are more aware of real-world science applications, i.e. that science is necessary for everyday life and not simply an isolated classroom activity, would be more likely to believe they will use science in a future career. When I compared the two questions, I found that not only was there no correlation, but it was the weakest correlation of any combination ($p = -.002$.)

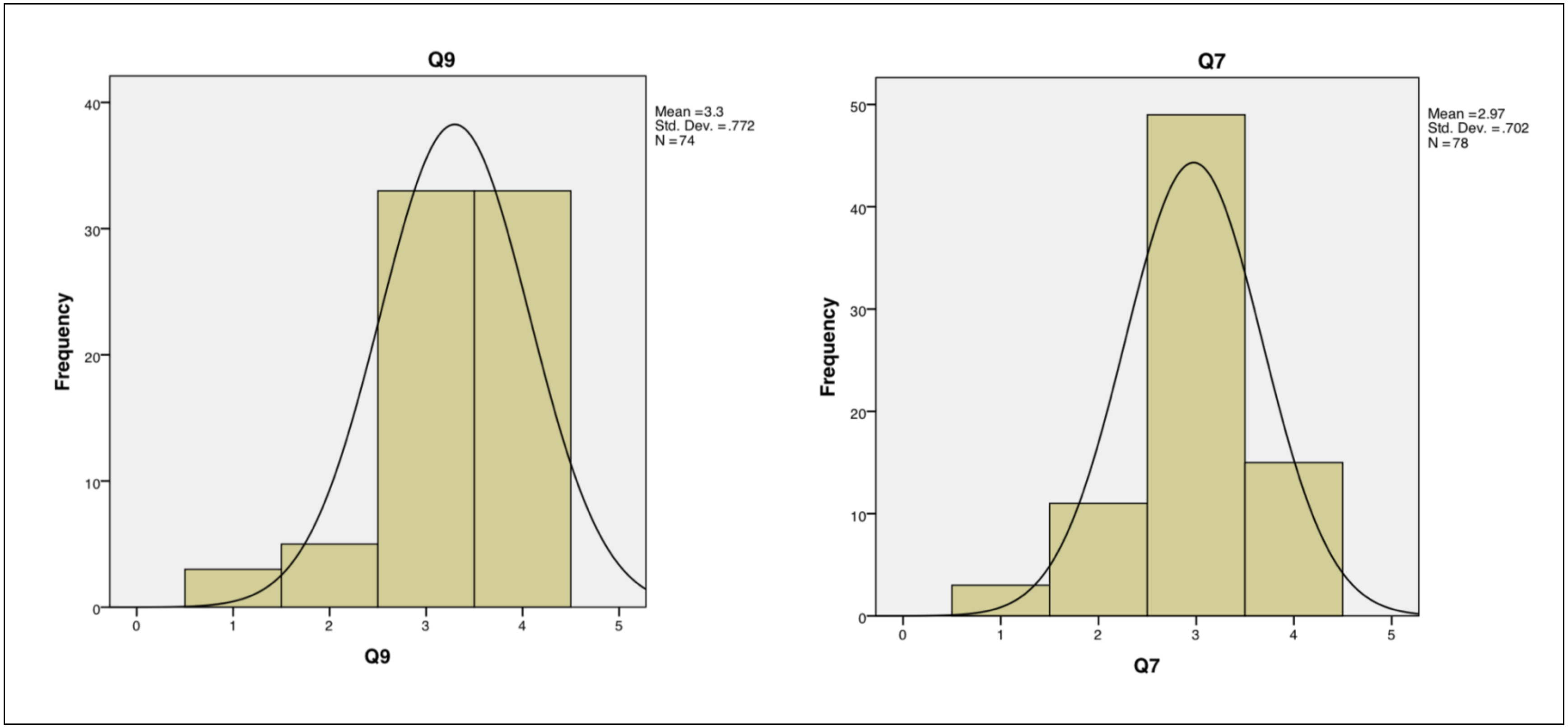

Figure 10. Histograms for Q9, “I enjoy learning science at school” and Q10, “Science is too hard for me”

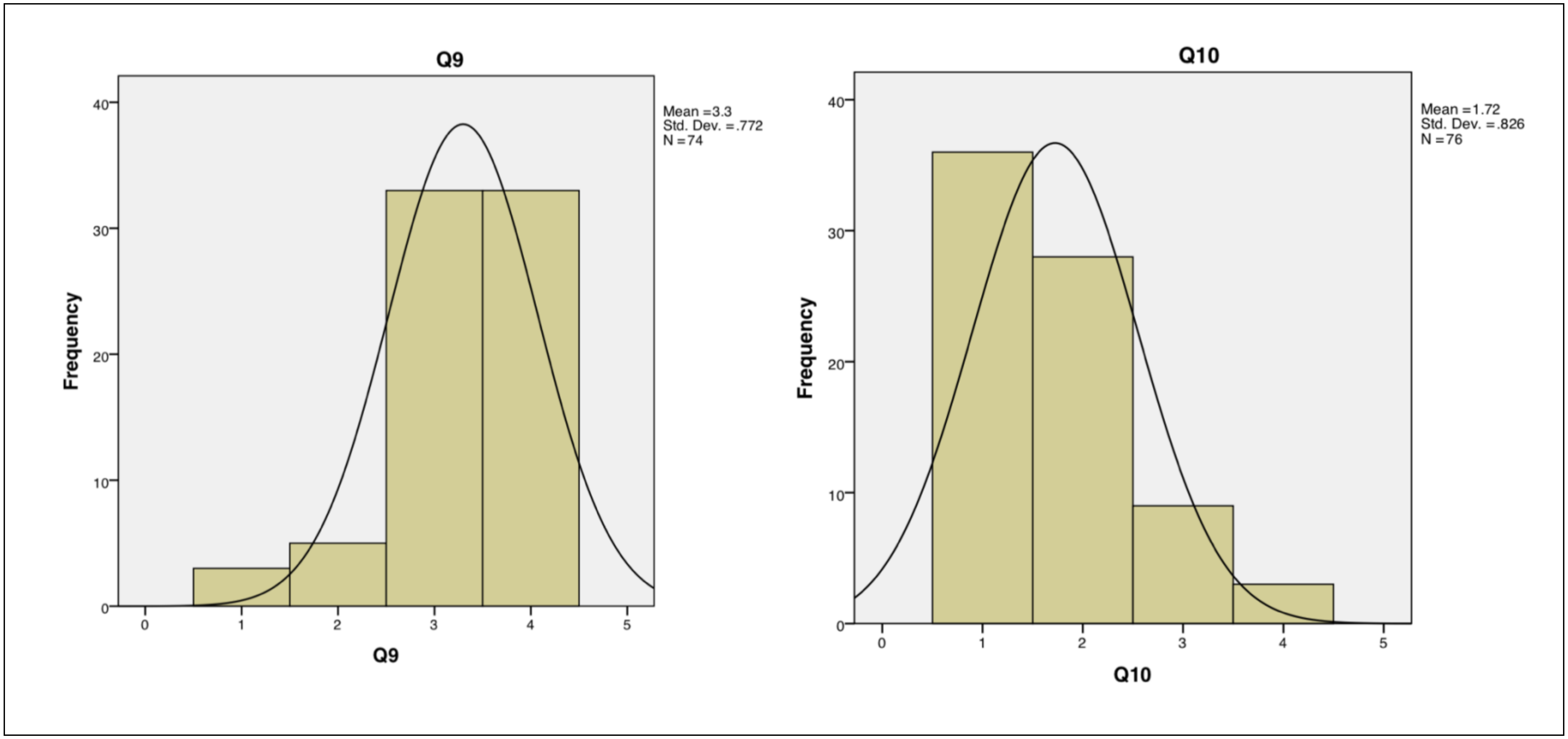

Figure 11. Histograms for Q9, “I enjoy learning science at school” and Q7, “I am good at science”

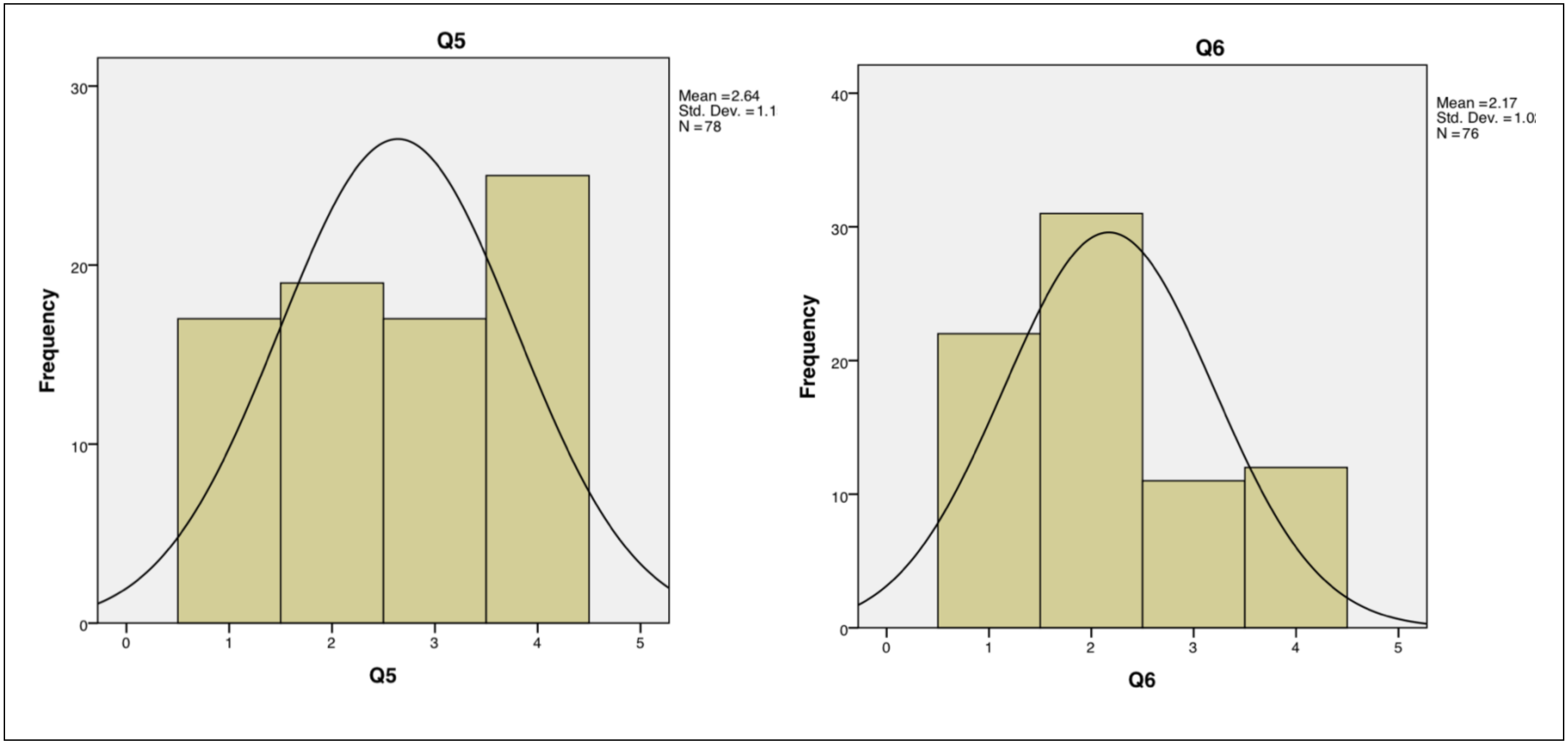

Figure 12. Histograms for Q5, "Science is often used outside of school" and Q6, "My future job will use science"

The data also revealed unexpected correlations in several points. There was a statistically significant negative correlation between a student's grade in school and their response to Q10, "Science is too hard for me" (Table 3). This suggests that the older students are, the more confident they feel in their skills. Interestingly, there was almost no correlation at all between a student's grade and Q7: "I am good at science" (Table 3) despite there being a negative correlation between Q7: "I am good at science" and Q10: "Science is too hard for me" (Figure 7). However, I found data that did not support this finding when applied to middle- to high-school students in the literature. Suter (2014) found that, on average, the confidence levels of students dropped fairly consistently each year between 7th and 12th grade, even as their actual performance levels stayed within a similar range. Yet, students with higher confidence levels in 7th grade did still have higher levels of confidence by 12th grade, despite the drop, when compared to students who began with lower confidence levels. I am curious if the age of the students made a difference, for instance if students will gain confidence until a certain point, and then begin to lose faith in their skills. Unfortunately, my research cannot answer this, and I could find no literature that explored longitudinal studies which included elementary through high school reports.

I was surprised to find that many of my assumptions were not supported by the results of my study, despite finding support for them in the literature. However, when reviewing the survey several possibilities come to mind which may have caused this disconnect. The survey wording could have been the issue; as I used different wording than many of the studies I found in the literature it is possible that I received different results. Desimone (2011) cautions against using non-validated surveys because you cannot have confidence in the constructs that are being assessed; you cannot be sure that the prompts are being interpreted with consistency. I changed the survey question wording to more accurately reflect the young age and lower language skills of the population I was working with. Another possibility is in the procedures followed. Because their teacher gave them the survey, instead of a neutral party, there is a potential that students chose answers they felt their teacher would want instead of how they really felt. Perhaps the biggest difference between my research and the literature though was the age of the participants. There are few conclusive studies into these themes which focus on elementary-aged students; the vast majority focus on middle-school, high-school, or university students. It is very possible that the students simply did not understand the questions or did not have the ability to accurately assess themselves in a consistent manner. This is where it would have been meaningful to have a pre-survey to compare to the post-survey I collected, however that was not possible and remains an unanswered question.

Another issue is simply the difficulty in assessing the effect of informal science learning when compared to formal science learning (NRC, 2001). Because formal programs have regular and frequent contact with students, they are able to conduct formative assessments which give them a more accurate picture of achievement and changes over time than a summative pre- or post-assessment. The NRC (2001) describes how teachers can collect data in a variety of ways which accurately match the activities they're assessing, ranging from classroom dialogue, portfolios, questioning, assessments ranging in formality from quizzes to end-of-unit tests, etc. Due to the limited interaction time with students participating in this blended informal-formal science program, data of that type was not able to be collected. It is very possible that additional, varied assessment would provide different or more detailed results.

Implications

While my research was inconclusive on several of my assumptions, it did provide additional support for prior research found in the literature. My data hints at a positive correlation between student attitude towards science and their self-perceived confidence levels in practicing it (Figure 7), but only when comparing how skilled a student rates themselves in science and their perceived challenge level when tackling STEM content. While my data was not conclusive in this area, several major studies support this conclusion and show that this correlation continues past elementary school and well into a student's academic career (Csikszentmihalyi & Hermanson, 1995; Gormally et al., 2009; Heaverlo, 2011; NRC, 2009; Suter, 2014). Various studies also show that interest in science generated from participating in informal science learning can have long-term impacts on students (Bamberger & Tai, 2008; Knapp, 2000; Salmi, 2003). Does this long-term interest have a positive relationship on student confidence when practicing science content areas, as current interest does? The literature is unclear, but if a relatively short interaction with informal science learning, such as a single field trip, can impact student interest years later then it is certainly worth exploring more in-depth. In addition, Suter (2014) found that each additional science museum visit increased student achievement on assessments roughly 5%. With such a strong impact for a short time, informal-formal science partnerships could be a time-efficient way to improve both student attitudes and achievement in science.

Finally, my study represents one of a very small number which examine the effect on elementary-aged students. Could partnerships established in elementary school continue to provide benefits as students age into secondary and higher education? Will those partnerships boost early student interest in science, encouraging them to take more STEM course as they grow up?

The goal of science education reforms, such as the NGSS (2013), is to improve student achievement and improve societal scientific literacy (NSB, 2010). By continuing research into the science programs that elementary students participate in, we can begin "informing decisions about curriculum and instruction and ultimately improving students learning" (NRC, 2001, p. 221).

Reflections

Personal Growth

I was fortunate enough to grow up with a family of science educators who instilled a deep curiosity of the world around me which has continued well past my childhood. While I knew the personal benefits this has provided me, both professionally as an educator or through the simple constant amazement and wonder that curiosity brings out in me, I had never looked for academic studies to justify my experiences. Through my journey exploring the body of literature on science achievement, learning, attitude, and how all three flow through each other, I am even more convinced of two things: (1) that a lifelong, childlike sense of wonder and awe is crucial for both personal satisfaction and academic achievement in the sciences, (2) that it does not necessarily require costly, time- and material-intensive curriculum to instill that view in our students. We have longitudinal data that shows even a single experience that brings excitement and personally-guided inquiry can benefit students academically, even go so far as to shape their future careers.

While I also significantly stretched my research and writing skills, my biggest takeaway for my classroom is to continue nurturing the small moments of joy students experience when they encounter something new, to resolve myself into encouraging questions and sometimes leaving students without a set answer. Curriculum changes, but no matter our available resources, teachers can and should focus on bringing a sense of wonder into their classrooms.

Challenges Experienced

Several issues came up when it came time for data collection. The first issue was a delay in IRB approval. This set the data collection timeline back several months and eliminated the possibility of conducting pre-program surveys as the program start date could not be changed. However, because the program participants were not officially finalized until a few weeks before the program began, I had to wait for the next IRB meeting which was not until after the program had already begun. While I was unable to assess changes in student attitude and achievement over the length of the program, I was still able to collect meaningful data showing post-program responses. These surveys allowed me to still compare relationships between student attitudes towards science and their confidence when participating in science lessons. I was able to collect data in this area that supported research found in the literature regarding this relationship (Csikszentmihalyi & Hermanson, 1995; Gormally et al., 2009; Heaverlo, 2011; NRC, 2009; Suter, 2014).

Next, I had hoped to compare the effect of this blended informal-formal learning program on science assessment scores. However, due to the privacy of the minors in the program, I could not access student scores on standardized science tests, nor work with students who were not involved in the partnership to compare a control to the participating cohort. Because of this, I had to rely on self-reporting of achievement levels. As seen in Gormally et al. (2009), it is possible that the self-reporting reflected over- or under-confidence. Without access to actual achievement scores, I cannot independently verify how accurate the students were in estimating their own achievement levels.

Another issue was delivery failure to at least one rural program site, which resulted in a returned-to-sender survey package. While I was able to contact each site to see who didn't receive it and hand deliver the package, it is possible this may have contributed to a smaller survey sample size due to a reduced timeframe for that site to effectively distribute and collect the surveys provided.

I also received incomplete survey packages and/or surveys that failed to remove identifying markers, such as student names. I preserved anonymity by transcribing all answers in an Excel file separate from the original surveys and removed any references to school names. I was able to send out a mass email asking site leads to double check they sent back both student surveys and teacher surveys, but I received a teacher survey separate from a batch of student surveys and was unable to identify if they matched while still preserving anonymity. Some students filled out the Likert scale responses incorrectly, checking two sometimes conflicting answers. Two students filled the entire survey out with "yes" or "no" put instead of checkmarks, but because they used multiple responses it could not be determined what their answer was. In addition, the young age and less advanced English skills of some participants made their open-ended writing responses very difficult to read and thus could not be properly coded.

One of the most significant issues was the lack of teacher surveys returned. While six teachers were involved in the program, only two returned surveys. This forced the removal of the entire teacher survey research section and prevented a full comparison of my research to the themes found in the literature. This and the lack of a pre-survey to analyze changes over time for participating students and teachers were the biggest barriers to drawing reliable conclusions.

What to Do Differently Next Time

There are several significant changes I would choose if given the opportunity to conduct this research again. The first would be to reach out to possible participants much earlier, establishing the official partnership at least six months earlier so that IRB approval could be requested and provided before the program began. I would seek full IRB review so that I could include student achievement data and possibly interviews. In this way, I would have access to pre- and post-survey data and test scores that could be utilized to assess the direct impact the program had on participants. With enough time before the program, it may have also been possible to reach out to other teachers at each of the formal education sites who would be willing to provide pre- and post-survey results from their students who did not participate in order to establish a control to compare the data to.

The next change I would make would be to hand-deliver the surveys to each participating site. There was an issue with mailing that could have contributed to a lack of data from participants; hand-delivery would allow me to ensure that each site received their materials while still allowing for anonymous survey-taking. I would also be able to answer questions about the process and go over the directions to ensure that both students and teachers filled out the surveys correctly. Despite providing written directions with the surveys, many were filled out incorrectly or missing data, so it is possible the directions were not read or were not understood.

Finally, I would finish the blended informal-formal science learning program a month earlier. This would allow more time for participants to fill out the surveys and allow me to better follow-up if data was not returned. The end of the year is a very busy time of year for classrooms, and I lost communication with several teachers once the school year ended. The lack of time could have led teachers to choose not to participate, and I could not check in to see statuses or offer help.

Future Research

The information found in the literature, coupled with the data my research provided, led to many unanswered questions that I would love to see explored. The most significant area I would like to investigate is longitudinal tracking of student attitudes and achievement throughout elementary. While there is significant research into this area, it is almost exclusively focused on students in high-school or university courses, with a lesser amount including middle-school students. I was unable to locate any longitudinal data that tracks elementary students and into secondary education; by filling this hole teachers and administrators will be able to make better decisions about programming and curriculum in the elementary level to ensure that students are set up for a lifetime of success early.

I would also like to compare actual science performance assessment scores with the confidence levels that students self-reported. Gormally et al.'s (2009) findings that students with lower test scores were more confident was an interesting result, especially when coupled with the results showing that higher levels of interest and achievement were usually positively correlated with confidence (Csikszentmihalyi & Hermanson, 1995; Heaverlo, 2011; Suter, 2014). Are students who are more interested in science likely to continue tackling it, even if it is challenging? Will students who over-estimate their confidence pursue more science courses, thinking success is possible, or less because they think they already know it? Can lower-achieving students benefit from excitement-boosting activities, such as informal science learning (NRC, 2009), to catch up to their peers over-time? These questions have important repercussions on science education and promoting student achievement in STEM content areas so further research would be very beneficial (NSB, 2010).

Finally, I would like to explore the affect that informal science learning programs have on formal science teachers. The majority of the literature focused on its effect on student attitudes and achievement, but very little on how it may influence a teacher's attitudes or pedagogical choices in their classroom. Heaverlo (2011) found that "science teacher influence correlated significantly with science interest...[and] also correlated significantly with science confidence" (p. 66). Can increasing the interest and enthusiasm for science that a teacher personally holds increase their ability to effectively deliver science content? It seems reasonable to expect such a connection to hold true, but we cannot establish a correlation without research. Branching from this idea, what kinds of programs can instill greater interest or confidence for teachers? Can visiting informal science institutions increase a teacher's confidence and ability to teach, as they can increase student mastery of content skills (Suter, 2014)? While reforms in science education have not been very effective in producing the desired growth (NRC, 2007), is that a failure of the curriculum? Or is it a failure of professional develop programs to properly guide teachers on how to achieve conceptual understanding in their students? Much research needs to be conducted before we can answer these questions.

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Appendices

Appendix A—Student Survey

What Do I Think About Science?

What grade are you in? ____

For the questions below, please mark how much you agree or disagree with the statement:

	Strongly Disagree	Disagree	Agree	Strongly Agree
1.When I work with other students on a science problem, we help each other figure out the answers				
2.Science is mostly just memorizing facts				
3.I like using science to solve problems				
4.My science teacher asks us to explain our thinking				
5.Science is often used outside of school				
6.My future job will use science				
7.I am good at science				
8.Science helps me answer my questions about the world				
9.I enjoy learning science at school				
10.Science is too hard for me				

1. List three ways you use science **during** school: ____________________________________

   ____

   ____

2. List three ways you use science **outside of** school:__________________________________

   ____

   ____

3. What is your favorite way to use science? ______________________________________

   ____

   ____

Appendix B—Teacher Survey

Science Practices in the Classroom

What grades do you teach? ____

Weekly, how many minutes of science instruction does your class receive? ______________

How many years have you taught science? ________________________________

What is your highest earned degree? ______________________________

Please rate your familiarity with each concept:

	I have never heard of this	Somewhat familiar	Familiar	Very familiar	This is A Major Component of My Curriculum
Inquiry-based Learning					
Problem-based Learning					
5 E's					
Next Generation Science Standards (NGSS)					
Informal Science					

How many minutes, on average, do you use each listed item in your science instruction each week?

Item	**Length of Usage**
Electronic Technology (computers, SMART boards, etc)	
Lecture	
Group Work	
Videos or Animation	

Interaction with a Professional Scientist (visit, interview, etc)	
Textbooks	

Please rate how well you agree or disagree with each statement

	Strongly Disagree	Disagree	Agree	Strongly Agree
1.I feel supported by my administration when teaching science				
2.My students are equipped to solve real-world problems				
3.I use science outside of the classroom in my everyday life				
4.My school's science curriculum includes content that addresses my region				
5.My district provides adequate science professional development				
6.I discuss current issues and discoveries during my science lessons				
7.I regularly collaborate with other teachers to adjust and plan my science curriculum				
8.I feel confident in my ability to teach science				
9.My administration provides adequate and appropriate science materials				
10.I stay on top of science advances through research (news, journals, etc)				
11.I have used outside groups (museums, scientists, etc) in my science instruction (*excluding iGrant*)				
12.I have enough time to teach science				
13.My school's science curriculum addresses current issues				
14.My students are curious about science				

What is the biggest problem in science education today? ______________________________

____

____

____

What question do you wish we had asked? ______________________________________

____

____

____

Appendix C—Letter to Parents

Consent Form

Student Surveys for Informal Science in the Classroom Research
Kellie M. Crawford, EWU Masters of Education Candidate at 509.499.5979
Gus Nollmeyer, Assistant Professor at EWU Education at 509.359.4381

Investigator's Statement

Purpose and Benefits

The goal of this research is to discover areas where formal science instruction in the classroom could be supported by outside, informal education facilities. This research will be conducted through two surveys, one given to teachers and the other to students, at the end of the 2016-2017 school year. These student surveys will explore attitudes towards current science instruction and areas where students feel they need additional support. This anonymously collected data will be made available for teachers and informal education facilities to guide curriculum choices and ensure that students receive appropriate science education in an engaging and immersive manner. This is a student research project intended to fulfill the thesis requirements for Kellie Crawford.

Procedures

Students will receive will receive the survey in June 2017. Their classroom teachers will administer the surveys, which should take no longer than 15 minutes. The surveys ask students to answer what level they agree or disagree with on ten different questions and to answer three open-ended questions on the science activities they engage in. These questions are designed to assess general feelings and seek to avoid overly personal or sensitive topics. Questions include ones such as “Science is too hard for me,” “I like using science to solve problems,” and “list three ways you use science outside of school.” All students are free to not answer any questions they may object to. No audio or video recording will be conducted.

Risk, Stress or Discomfort

To minimize risk, researchers will not have access to student names and will not be able to match individual surveys to schools. Researchers will not be present during the survey administration. The questions seek to avoid any personal information and teachers are instructed to censor any comments students make on the surveys which may lead to personal identification before the surveys are returned to researchers. To further ensure anonymity, consent forms will be sent in separate envelopes from the surveys, to be returned in pre-marked envelopes. Once the forms and surveys are returned only the researcher will have access. The surveys will be administered by the regular teacher during their normal instruction time to minimize any disruption or discomfort. Students are not required to answer any questions they may object to. The surveys are designed to mimic common informal assessment questions teachers use in their normal instruction. There are no anticipated side effects for these surveys.

Other Information

Participants who have difficulty reading or writing are allowed accommodation to assist their completion of these surveys. The identity of subjects will be completely anonymous and each student can withdraw their consent for the survey at any time without penalty in choosing to not participate. No participants or researchers will receive inducements of any kind for participation.

Signature of Principal Investigator Date May 29, 2017

Subject's Statement

The study described above has been explained to me, and I voluntarily consent to participate in this survey. I have had an opportunity to ask questions. I understand that by signing this form I am not waiving my legal rights. I understand that I will receive a signed copy of this form.

Signature of Subject Date

Signature of Parent/Legal Guardian Date

[for adult who is unable to provide consent]
Signature of Subject Advocate Date

*Subject may usually waive the right to the advocate by signing in that space as well.

If you have any concerns about your rights as a participant in this research or any complaints you wish to make, you may contact Ruth Galm, Human Protections Administrator, at (509) 359-7971 or rgalm@ewu.edu.

Appendix D—Letter to Teachers

Consent Form

Teacher Surveys for Informal Science in the Classroom Research
Kellie M. Crawford, EWU Masters of Education Candidate at 509.499.5979
Gus Nollmeyer, Assistant Professor at EWU Education at 509.359.4381

Investigator's Statement

Purpose and Benefits

The goal of this research is to discover areas where formal science instruction in the classroom could be supported by outside, informal education facilities. This research will be conducted through two surveys, one given to teachers and the other to students, at the end of the 2016-2017 school year. These teacher surveys will explore the attitudes and pedagogical practices science teachers are currently using. This anonymously collected data will be made available for informal education facilities to guide curriculum choices in providing support to classroom teachers and supplement science education in an engaging and immersive manner. This is a student research project intended to fulfill the thesis requirements for Kellie Crawford.

Procedures

Teachers will receive the survey in June 2017. The survey should take no longer than 15 minutes. The survey will ask teachers to rate their familiarity and usage levels with different science pedagogical practices, provide information on how much time is spent on science instruction in their classrooms, and what tools they use when teaching. Additionally, there are fourteen questions asking teachers to rate their level of agreement with statements such as “I have enough time to teach science,” “my schools’ science curriculum addresses current issues,” and “my district provides adequate science professional development.” These questions are designed to assess general feelings and seek to avoid overly personal or sensitive topics. All teachers are free to not answer any questions they may object to. No audio or video recording will be conducted.

Risk, Stress or Discomfort

To minimize risk, researchers will not be able to match individual surveys to schools as surveys will be returned in anonymous, pre-marked envelopes separate from consent forms. Once these forms are returned only the researcher will have access. Researchers will not be present during the survey administration. The questions seek to avoid overly personal or sensitive information. One question asks for the teacher’s level of education; this is designed to assist in professional development offerings. Teachers may fill out their surveys on their own time when it is most comfortable to minimize disruption. They are not required to answer any questions they may object to. There are no anticipated side effects for these surveys.

Other Information

Participants who have difficulty reading or writing are allowed accommodation to assist their completion of these surveys. The identity of subjects will be completely anonymous and each teacher can withdraw their consent for the survey at any time without penalty in choosing to not participate. No participants or researchers will receive inducements of any kind for participation.

Signature of Principal Investigator Date May 29, 2017

Subject's Statement

The study described above has been explained to me, and I voluntarily consent to participate in this survey. I have had an opportunity to ask questions. I understand that by signing this form I am not waiving my legal rights. I understand that I will receive a signed copy of this form.

Signature of Subject Date

[as appropriate] Date
Signature of Parent/Legal Guardian

[for adult who is unable to provide consent]
Signature of Subject Advocate Date

*Subject may usually waive the right to the advocate by signing in that space as well.

If you have any concerns about your rights as a participant in this research or any complaints you wish to make, you may contact Ruth Galm, Human Protections Administrator, at (509) 359-7971 or rgalm@ewu.edu.

VITA

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