Inquiry-Based Science and Higher-Order Thinking Skills in Upper Elementary Science Education

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INQUIRY-BASED SCIENCE AND HIGHER-ORDER THINKING SKILLS
IN UPPER ELEMENTARY SCIENCE EDUCATION

by

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CHAPTER ONE

Introduction

Chapter Overview

Last summer I was asked to reflect on what I remembered about science in my personal experience as an elementary school student. I could not remember anything. My mind jumped to science in middle school and lessons in which we were active agents in our learning such as a nature walk or dissection. This caused me to ponder why I do not have any memories that stood out in that content area, clearly, I had learned science before middle school, but it was nothing that really stood out as exceptional. This past spring semester during student teaching, I was faced with thinking about the best way to teach science standards that would engage my students to be active participants in their learning. I felt equipped to teach science content, yet I was uncertain of what was the best way to teach this for my students. Although I knew what worked best for myself as a student, I was unsure how to integrate student-centered learning into my cooperating teacher’s lesson scope and sequence. Unfortunately, it was not something that my classroom had a lot of time to spend on, therefore I wanted to make the time that we did have more meaningful and efficient. In a recent professional development day for fifth-grade teachers, we discussed inquiry and discovery-based learning and how this was beneficial in many ways to our students. It gives them the chance to explore, research, problem solve, and reflect.
Given the engagement that I experienced as a learner at this recent professional development session and the goal of inquiry-based approach to science, I am motivated to create opportunities for higher-order thinking skill development in STEM curriculum. Therefore, I am asking: How can curriculum design in upper elementary science education enlist students in practice and demonstration of higher-order thinking skills? I want to see how designing and teaching inquiry units can further students’ higher-order thinking skills of synthesis and evaluation. In order to construct these lesson plans accurately despite there being updates to the Minnesota Science standards this year, I have looked at the current Minnesota Science standards and found overarching themes. More specifically I have found overarching themes in each of the subtopics of nature of science and engineering, physical science, and Earth and Space science in grades 3 through 5. Some of these overarching processes that the upper elementary grades study are different cultures and their influence on society in engineering, tools and mathematics, states of matter and how they change from one to another, simple machines and electric circuits, force and motion, rocks and minerals, the water cycle, water supplies and uses, the Earth’s surface, and human interaction with Earth’s systems. An important act of being a good citizen is taking care of where we live and our Earth. Our interactions with the world around us shape our environment that we live in and provide for future generations.

This year the Minnesota state science standards are being redone and with this renewal will come new changes. I have heard this from the district that I student taught at and they were asking one person from each grade to become a science expert and work
with making our science lessons more engaging and student-centered. My hope is that during this time, we can rework how we have been teaching science to our students and make it more engaging for all. I am constantly reflecting on my own teaching and how things go with my students. I know that part of this is taking a deeper look at what is the most effective way to teach science and what we gain when using the inquiry-based science model. In this chapter, I will be discussing the research question, background, and rationale for my capstone project. I will also be discussing the background of coming to my research question, professional experience, and first teaching experience.

**Background**

Last summer I took my teaching science in elementary course at Hamline University and it made me rethink the way that I looked at teaching science. It made me realize that encouraging students to wonder about the world and learning alongside them is the best practice. In this course, we had the opportunity to create science centers for our classmates. We would begin our class by coming in and exploring these activities and then have a reflection that followed. Even as adult learners, this was something that I looked forward to on a weekly basis and caused me to think differently about the world around me. I liked how it was hands-on and you were usually trying to see if you could solve a problem and then record your answers. An example of a science center would be creating your own bubble solution and comparing its effectiveness to store bought bubbles or seeing how many paperclips you could attach to a magnet before they fell off and lost their magnetism. I want to harness the energy that I felt during my science pedagogy class, and take it a step further and have inquiry-based learning in science that
allows students to problem solve, think creatively, and use higher-order thinking skills that they do not normally activate when participating in more traditional teaching and learning experiences.

The Purpose of My Research

Students can and should become better problem solvers and critical thinkers through having more experiences with higher-order thinking skills. For the purposes of this project, I am defining higher-order thinking skills as processes that lead students to use critical thinking and look closer at the information that they are working with and question possible outcomes, compared to the opposite of lower functioning learning such as rote memorization (Watson, 2019, para 4). When defining higher-order thinking skills, one can refer to the Bloom’s Taxonomy pyramid (Bloom, 1956). This was designed to refer to six levels that promote higher level thinking. The original levels were knowledge, comprehension, application, analysis, synthesis, and evaluation. These levels were revised to actions and processes instead of nouns: remembering, understanding, applying, analyzing, revising, and creating (Watson, 2019, para 4). Taking a closer look at the original pyramid leads us to explore analysis, synthesis, and evaluation as different ways in which our students can improve their critical thinking and higher-order thinking skills.

This capstone project is important to me because it reaches all types of students and different populations within the classroom. For example, I am interested in how this teaching would affect students with special needs and English language learners. I have found through my personal experience that these students sometimes can excel more
compared to their peers in science because it is not about academic language proficiency. Instead, science can be about the student’s wonderings and being engaged through a research question, exploration, looking at the data, and writing or concluding. Therefore, they are active participants in their own education. I am curious to see how these populations would perform compared to their peers in general education and to see how it was able to develop their higher-order thinking skills of analysis, synthesis, evaluation, and critical thinking.

This research is important to many different groups of people within the education system such as students, parents, educators, and policymakers. Looking closer at the way we teach elementary science is going to affect our students and how they experience and learn about the world around them. It will affect families as well because the students will have a different perspective of interpreting the life around them. An inquiry-based science curriculum could also spark interest in a student’s education journey that may lead to a future in that field as well. Whereas a different approach such as readings and tests may deter them from the subject altogether. Changing the way that we teach science could lead to our students doing more science-based activities at home as well and becoming more curious about the world around them compared to before.

Teaching elementary science through an inquiry-based model would affect many different stakeholders. First and foremost it would affect colleagues, such as other teachers because you are forced to rethink how we have been teaching our students this content and take a step back from being the head of the classroom and let the students have a more active role. We still guide them as facilitators, but we do different work in
this model. Teachers also learn alongside their students in a different way as they are experimenting and reflecting both as a group and as individuals. This type of instruction may feel uncertain to other colleagues who have been in the field for a long time, but I think it is important to reform our practices and continue to make them the best that they can be. Inquiry-based science education also affects policymakers because our standards need to be written in a way that we can take them and push our students further with that content. It also requires our administration to trust us more with lesson planning and curriculum development since there isn’t as much information currently available seeing as the Minnesota state science standards will be revised this year.

Professional Experience

I am a Master of Arts in Teaching (MAT) student; I obtained my initial license in Elementary Education K-6 this past spring. I have worked in schools for the past several years as an AmeriCorps member and as an Education Assistant in Special Education. I served a year with AmeriCorps and Reading Partners Twin Cities in East Saint Paul, Minnesota. In this position, I worked with students who were behind in reading. I was fortunate to work with the Hmong and Karen populations and developed my skills for teaching English language learners. As a site facilitator, I was also the main point of interaction for several groups of people: volunteer tutors, students, administrators, teachers, and so forth. It was at this job that I realized that I had a passion for making a difference in students’ lives early on in their elementary years and I began the Master of Arts in Teaching Program at Hamline the following summer.
During my time as a graduate student at Hamline, I worked during the day as a special education paraprofessional or education assistant. At first, I worked with students who had Autism Spectrum Disorder (ASD) and Developmental Cognitive Disability (DCD) in a high school setting. This was a great introduction and learning experience in what special education looks like in our schools. In the next academic school year, I decided to take a job as an education assistant working with students who have Autism Spectrum Disorder (ASD) in a higher setting, setting 4 rather than a setting 3 at my previous job. Within a setting 3 special education program, students are outside of the special education classroom 60 percent of the school day. In this setting students receive special education services in a general education classroom to provide them with their least restrictive environment. In a setting 4 special education classroom, you have a self-contained classroom within a school that is specifically for students whose home districts are not able to serve them because of resources, self-harm, harm to others, or property destruction. In a setting 4 school, the ratio of teachers and staff to students is significantly higher and more rigorous training is required to keep both students and staff safe.

This brought along another great experience to add to my teaching career. Half of my students were nonverbal in my classroom, so I learned how to use Augmentative Alternative Communication (AAC), core vocabulary, and sign language. In this position, I learned how important our nonverbal body language is and how we can change that to have better interactions with our students. We were trained in TCIT which is short for Teacher Child Interaction Training and it worked amazingly with our student body,
especially because of their high rate of trauma, being at an intermediate school district. Teacher Child Interaction Training was designed to improve the social, emotional, and behavioral competence for children 3-6 years of age. It has been shown to work effectively with teachers because it increases the self-efficacy and job satisfaction for early childhood educators (Teacher Child Interaction Training 2019). TCIT is used to reduce challenging classroom behaviors such as physical and verbal aggression, destruction of property, noncompliance, hyperactivity, emotional dysregulation, and negative teacher-child relationships. While I was working at the level 4 special education school, forming positive teacher-child relationships was crucial to our students’ success because the students coming to us had been anywhere from 1-3 schools prior and had poor experiences. These experiences working with children outside of mainstream classroom settings prepared me to meet my future students with attention to their differences and confidence that I would be able to relate to them with humanity.

My first teaching experience as the lead teacher of the classroom came in spring of 2019 when I student taught. I worked with fifth graders and had twenty-six students in my class. I enjoyed working with a different age range than I had previously. I also enjoyed the more difficult content of general education and how much further students could push themselves in thinking critically. I had recently taken the Teaching Science in Elementary course at Hamline and had a lot of questions and wonderings as to when and how science would be taught in this classroom. Science was a part of the classroom every few weeks. The three fifth grade teachers would teach from Foss kits (interactive science instruction kits for teachers and students to use in the classroom) and rotate through them
class by class. There were units that went along with them and were well planned out. While it was evident that they had been teaching these kits and units for a long period of time, the topics were still relevant to us and our world today. While I was there, I taught a unit on erosion and renewable and nonrenewable energy resources. During the different investigations, my students were engaged and enjoyed doing the hands-on activities and some reflection as a group or as individuals. For example, there was a unit called renewable and nonrenewable energy resources. In this unit, we were looking at humans’ impact on our planet and the repercussions that we’re having to deal with today because of our actions. This unit included reading two informational texts about resources and then having students demonstrate their knowledge of the material. At the end of the unit, there was a traditional summative assessment. Within this first teaching experience, I learned that this was a teacher-led curriculum that still relied more heavily on rote memorization for the final exam. I would like to present an inquiry-based curriculum that promotes student’s wonderings and curiosities and puts them to action in experimentation, data collection, analysis, and reflection. I would also like to make the investigations that we do more relatable to their everyday life. I think that switching these two factors would cause a huge shift in the way we teach elementary science and lead our students to become lifelong learners and better critical thinkers.

**Summary**

In conclusion, I am going to study how inquiry-based learning in upper elementary science instruction can improve students’ higher-order thinking skills of synthesis (inferring relationships among sources) and evaluation (students making
judgments about the value of ideas, items, and materials). I chose synthesis and
evaluation because I believe that they are important skills that can be transferred across
other content areas and contexts of everyday life. I think that if students felt more
comfortable with looking at information and analyzing it better, they could come to more
profound thoughts over the course of their educational career. I came to this topic through
taking my Teaching Science in Elementary and during my time student teaching. While
in my course, we discussed the importance of inquiry and student-centered instruction.
During my student teaching with fifth-grade students, I found that science instruction was
teacher-centered. I think that through using inquiry-based science education in the upper
elementary grades, we can improve students’ higher-order thinking skills, especially
those of synthesis and evaluation. Another important factor for my interest in this topic is
that since the Minnesota science standards are being redone this year, I think it is a great
time to reflect and take a closer look at how we are teaching science to our students.

Chapter Two will contain a literature review that will inform readers on the large
conceptual issues related to my topic such as inquiry-based science. It will also look at
the higher-order thinking skills of synthesis and evaluation and how they are able to
develop further with an inquiry-based pedagogical approach. The literature review will
provide an elaboration on what experts in the field say so that we’re able to move forward
with this capstone project and have a solid background of knowledge to base this project
on. There will be a reflection portion for myself to reflect on what the experts have to
say. Chapter Two will also focus on connections with other researchers and communities.
CHAPTER TWO

Literature Review

Part of the reason that I wanted to become an educator was to instill a lifelong love of learning within my students. As educators, we would like our students to be curious and have the opportunities to wonder alongside them. In doing this, we will be inviting them into an engaging environment with a strong classroom curriculum that keeps them active participants in their learning. As we take a closer look at science education in elementary schools, it seems to have received less attention and time to perfect the craft of what is the best way to teach this subject. If we alter our pedagogy to be more student-centered and use an inquiry-based curriculum, then our students will gain a deeper understanding of the material.

When students research a science topic of their choice, it would be both highly interesting and relevant to them. Using the 5 E Inquiry-Based Model of Instruction (engage, explore, explain, elaborate, and evaluate) their higher-order thinking skills of synthesis and evaluation will grow even more. The students’ problem solving, and critical thinking skills will also grow at a rate much faster than those who are learning from a more traditional pedagogical approach. During my student teaching, I taught science from a science kit and while it was more interactive, I felt as though the students’ use of higher-order thinking skills was still only moderate. As I enter a new school year and conduct this research, I am asking: How can curriculum design in upper elementary science education enlist students in practice and demonstration of higher-order thinking
skills? As I am investigating this research question, I will go over the details of what inquiry-based science is, the relationship between inquiry-based science and higher-order thinking skills, Next Generation Science Standards (NGSS), and phenomena-based science instruction.

**Minnesota State Standards**

Minnesota Department of Education defined science as, “the active study of the natural and human-made world, including processes, structures, designs, and systems” (2019, para 1). Students observe and record findings, execute investigations, and come to conclusions that they share with one another (Minnesota Department of Education [MDE], 2019, para 1). “Scientifically literate young people can understand basic science concepts, use skills for doing scientific investigations, solve technical problems, and design technologies for today’s world” (MDE, 2019, para 1). There has already been much work on having our students understand basic science concepts and using skills for scientific investigations. There is room for more growth in having students solve technical problems and design technology for today’s world.

In order to ensure that all students receive a high-quality science education, educators have state standards that they must teach and guide our lesson plans. Students’ science performance is gathered on the Minnesota Comprehensive Assessment (MCAs) in both fifth and eighth grade. As science and technology continually change and move forward with new information, we too must update our science standards for teaching this content area. Minnesota is a lead state in developing the Next Generation Science Standards (NGSS). Minnesota and many other states work together to create standards
that can be adopted by other states as well. “The standards are based on *A Framework for K-12 Science Education* developed by the National Research Council. The framework sets the vision for science education and identifies science and engineering practices, core disciplinary ideas, and cross-cutting concepts” (MDE, 2019, “Standards, Assessments, and Graduation Requirements”).

“Minnesota has shown a high commitment to science through its recent standards revision process and in its numerous partnerships” (Next Generation Science Standards [NGSS], 2019, para 2). In Minnesota, we have a diverse population of individuals and types of living that ranges from urban to very rural (NGSS, 2019, para 3). Minnesota has a commitment to reducing the achievement gap in our state, especially in the Science Technology Engineering and Mathematics (STEM) content areas (NGSS, 2019, para 2). Minnesota has partnered with SciMath to have an online resource readily available for educators that has the standards, benchmarks, common misconceptions, and more.

Minnesota has also created the MN STEM Network, which is for creating partnerships with other organizations that can enhance our students’ involvement in these content areas. By creating these resources and continually building upon them, Minnesota is making great efforts to offer a higher quality education in science to our students, have a wider variety of resources available to all, and to continue to grow alongside this ever-changing field.

**Next Generation Science Standards**

Since the beginning of the creation of The Next Generation Science Standards, forty of our states have paid close attention to this work in progress (Harris et al., 2017, p.
“The overall objective of these proposed changes is to align K-12 science education with current trends in technology and career needs” (Harris et al., 2017, p. 54). This goal is widely accepted and supported by all educators. There is some concern when it comes to the topics of teacher preparedness and access to resources and technology in order to make these new standards effectively implemented statewide (Harris et al., 2017, p. 56). Therefore, Harris and his colleagues set out to survey K-12 public education teachers across 16 states and 214 schools to see what their ideas and concerns were regarding these new science standards. Their findings revealed that, “most of the teachers were not knowledgeably equipped to fuse the proposed changes in standards with the current curricula and their teaching plans” (Harris et al., 2017, p. 54). Teachers that were from “poorly resourced schools” had concerns about updating their curriculum and having access to the resources needed to successfully carry out lesson plans aligned with the new standards (Harris et al., 2017, p. 59). On the other hand, teachers from schools that had access to many resources found that these changes can be easily made (Harris et al., 2017, p. 59). The importance of professional development for teachers surrounding these new standards were discussed along with encouraging teachers to learn alongside their students within this new framework of teaching science. Harris et al. (2017, p. 60) stated the concern of many individuals when saying, “It must be noted, however, that the success in the implementation of these programs depends on the level of financial support either from the schools or the state” (p. 54). If teachers do not have the support they need from their schools, district, and state, then implementing these standards and reworking
the way we teach science will become more difficult than it should be and ultimately unsustainable.

Technology was another concern that came up for educators in Harris’s study. While students are proficient at using technology with social platforms, they are not as comfortable utilizing them for academic purposes (Harris et al., 2017, p. 60). The teachers who were surveyed made an important note that in order for technology to be successful within their lessons, time must be taken to teach students how to use the technology in isolation prior to using it in conjunction with a content area such as a science project (Harris et al., 2017, p. 60). Another concern is access to technology and because our public schools are funded through property taxes, there are discrepancies as to what is available within different districts across the state (Harris et al., 2017, p. 60). Overall, the study found that, “those schools that were better equipped also showed a more sympathetic approach to NGSS while the poorer schools expressed more concerns” (Harris et al., 2017, p. 60). Harris stated that the hope for carrying out the reform of our science standards is that these details are thought out thoroughly before implementation and that we do our best to carry these out to the fullest across the state (2017, p. 60). In the near future, it will be interesting to see data comparing schools who have been implementing NGSS more closely, compared to those who have fewer resources and have to be more creative when working with this new approach.

Another important aspect of the new Next Generation Science Standards is that we need to ensure that there are educational systems in place that will support our instruction well. The NGSS standards have three-dimensional learning goals;
three-dimensional learning (the change in curriculum, assessment, and instruction), scale and the change for multiple scales within the educational system, and within diversity offering a culturally responsive pedagogy to our students (Anderson et al., 2018). One of the changes with the new standards is, “the performance expectations of the NGSS describe goals for science learning as three-dimensional engagement with phenomena: Students should use crosscutting concepts and disciplinary core ideas as they engage in scientific practices focused on phenomena in the material world” (Anderson et al., 2018, p. 1027). For this change to occur, we must shift our pedagogy in elementary science to be inquiry-based and incorporate authentic learning experiences that allow students to think critically about the world around them. Anderson brings up a valid point when saying that most classrooms do not provide this experience for our students as of now. Students create projects and assignments in return for a grade. Whereas now, students are going to be encouraged to explore their wonderings and problem solve in an investigative approach about real-world problems. This shift will cause classrooms and student learning to change a significant amount (Anderson et al., 2018). These changes will need to have coordinated planning on many levels or scales such as teachers, schools, school districts, statewide, and so on. Another concern is how to implement a curriculum that is rigorous and culturally responsive to the diversity that we have within our classrooms and schools (Anderson et al., 2018). This is a challenge due to the access to resources and will continue to be something that we work towards managing better and solving.

Overall, the Next Generation Science Standards (NGSS) come from a good place of wanting to keep our instruction up to date with the STEM world that is constantly
changing and evolving. As with other reforms that have happened, there are some uncertainties and worries that come with the change. While we may not be able to solve more equitable funding among our schools, we can focus on different instructional approaches that can assist us in this update of practice. Using an inquiry-based pedagogy, students will become more actively engaged and will work with the content deeper, as the standards call for. Another aspect of the new standards that we must implement is making connections from the content to the real world around us, otherwise known as phenomena.

Need for Reform

In order to look at the benefits of inquiry-based science instruction on our students, we must first take the time to define what inquiry-based science is and what the key components of its instruction are. As educators take a closer look at the pedagogy surrounding science education, we have found that there is a need for reform. Dr. Robin Gillies, a professor in the School of Education at the University of Brisbourne, Australia talked with Dana Bulba of the Smithsonian Science Education Center and stated that:

I have also been concerned for some time in the relatively mediocre performances of many students in Australia, the USA, and the UK on standardized international tests such as PISA and TIMMS, particularly when I see how consistently successful Finland, Singapore, the Republic of Korea, Chinese Taipei, and Japan have been on these same tests. (as cited in Bulba, 2019, para 2)

Dr. Gillies’s suggestion after studying cooperative learning for the past twenty years is to incorporate the investigative approach of inquiry science and pair it with cooperative
learning so that students are learning to work at a deeper level with the science content that we are teaching them (Bulba, 2019, para 2). From her research, she has also found that cooperative learning in math, science, and social science content areas have led to greater student engagement, socialization, and learning (Bulba, 2019, para 2).

Conversations surrounding student-centered education and cooperative learning have led us towards inquiry-based education.

**Inquiry-Based Instruction Definition**

“Inquiry-based science adopts an investigative approach to teaching and learning where students are provided with opportunities to investigate a problem, search for possible solutions, make observations, ask questions, test out ideas, and think creatively and use their intuition” (Bulba, 2019, para 3). This pedagogical approach gives students a hands-on experience with science that causes them to use higher-order thinking skills and problem solving, rather than textbook reading assignments and rote memorization that can be seen in a more traditional pedagogy. “Such learning is consistent with the social constructivist learning perspective which emphasizes the idea that knowledge is actively constructed by the learner, in contrast to being transmitted directly from the teacher to the learner” (Akuma et al., 2018, p. 65). Giving students the opportunity to build upon each other’s prior knowledge and make new connections will help them gain a fuller understanding of the content and help them remember it better in the future. When students make neurological connections from past to new knowledge, it is more meaningful and easier to remember compared to taking in the new information in isolation.
For inquiry to be successful, teachers must “recognize the importance of presenting problems to students that will challenge their current conceptual understandings, so they are forced to reconcile anomalous thinking and construct new understandings” (Bulba, 2019, para 3). In doing so, the teacher must give up a lot of their control in the classroom and become a facilitator compared to the one source of knowledge that leads the classroom through a sequential set of steps. In a way, a teacher new to this pedagogy may feel vulnerable at first. Their goal in inquiry-based teaching is to be guiding students, helping them understand what they’re researching or finding, and providing detailed feedback.

Preservice Elementary Teachers’ Experience with Inquiry.

Another important aspect of this to consider is what are our teacher’s experiences with learning about and creating lessons that are grounded in inquiry-based instruction and scientific inquiry. This is important to consider for both current educators as well as preservice teachers. In elementary education teacher preparation programs, there has not been a large emphasis on inquiry-based education, therefore teachers may feel ill-equipped to instruct their classroom through this type of pedagogical approach (Amirshokoohi et al., 2013). In order to ensure that primary teachers feel comfortable with this teaching approach, we must make sure that they have a full understanding of what scientific inquiry within the classroom should look and feel like for both them and their students. Preservice elementary education teachers need to, “gain firsthand experience and develop a more in-depth understanding of inquiry-based learning as part of their training, especially in science content courses, so as not to replicate and reinforce
their previous traditional science experiences” (Amirshokoohi et al., 2013, p. 144). This is important because when teachers feel uncertain or uncomfortable with a new pedagogical approach, they tend to go back to the way that they were taught because they are more knowledgeable about it. Preparation must change for practices to change. The goal is for future generations to experience meaningful and engaging science learning at the elementary level that causes them to be and stay curious about the world around them.

Higher-Order Thinking Skills.

The success of all students in science has become a priority in countries throughout the world, as governments have increasingly realized that their economic futures depend on a workforce that is capable in science, mathematics, and engineering (Slavin et al., 2014). Due to this realization, there has been an increased focus of how we are exposing our future generation of scientists and elementary students to this content. In primary school, we’re given the opportunity to shape students’ experiences with different content areas. Therefore, we want to ensure that we are challenging them and causing them to become critical thinkers. Over time, there have been numerous different pedagogical approaches presented to educators such as an inquiry-based approach. Unfortunately, the research to support the higher-level thinking that inquiry-based pedagogy creates is predominantly secondary and has hardly any primary or elementary education sources. Slavin et al. (2014) stated, “While there have been several reviews of research on various aspects of science teaching, there has not been a comprehensive review of experimental evaluations of alternative approaches to elementary science education” (p. 871).
Another aspect of higher-order thinking in inquiry-based science to consider is the component of cooperative learning. Woods-McConney et al. (2016) focused on this type of pedagogical instruction to model the way that scientists research, share their findings with others, and build meaning upon each other’s work in order to move forward in new scientific findings. “This is especially important, since research on cooperative group work has shown that working and learning in groups improves achievement, motivation, social interactions and problem-solving in science” (Woods-McConney et al., 2016, p. 843). One can also relate this back to Lev Vygotsky’s social learning theory of how people learn more when they can listen to each other’s perspectives and thoughts because they get to interact socially instead of completing their work by themselves (Belyh, 2016). Woods-McConney et al. conducted a study in which they were tracking the specifics of when and how students were making connections with each other’s findings. After their study, they found that students did co-construct meaning when working in a cooperative learning model, but it was not for an extensive amount of time. The details of the study’s research were, “The maximum amount of time spent engaged in co-constructed meaning was 7.8 minutes out of a total of 180 minutes (two 90 minute lessons), which equates to approximately 4.3% of the lesson time” (Woods-McConney et al., 2016, p. 855). This begs the question as to what was the teacher’s role during this cooperative learning? How and were they properly facilitating the students if there was minimal co-constructing meaning happening? A teacher’s role in this pedagogical approach of inquiry-based science would be to guide students as needed, to assist them in making observations and connections with their peers, facilitating the students, and
keeping everyone on track timewise. There are many things that the teacher can be doing
during the lesson, especially since they do not need to be up at the front of the classroom
teaching everyone, they are given the opportunity to push students’ thinking and help
them make deeper connections to the content.

While facilitation is important, it also seems that teachers can influence students' capacities for critical thinking, but this must be intentional. Barack Miri et al. (2007) decided to explore if purposeful teaching of higher-order thinking skills in science led to increased critical thinking among students. Their reasoning behind this study was that, “Our ever-changing and challenging world requires students, our future citizens, to go beyond the building of their knowledge capacity; they need to develop their higher-order thinking skills, such as critical systems thinking, decision making, and problem solving” (Miri et al., 2007, p. 353). Therefore, in order to prepare our students for their involvement in the world of higher education or work as adults, we should be working on building these higher-order functioning skills with them beginning at an early age. “A large part of science education reform that is currently underway is a shift from the more traditional, textbook, rote learning to exploration, inquiry-based learning situated in real world phenomena” (Miri et al., 2007, p. 354). They also refer to Bloom’s Taxonomy’s levels of comprehension and state that the higher levels, which we hope to achieve with our students are analysis, synthesis, and evaluation. In Miri’s study, they defined higher-order thinking skills as, “an ‘umbrella’ encompassing various forms of thinking such as critical, systemic, and creative thinking” (2007, p. 355). They chose to focus on critical thinking rather than more specific types of higher-order thinking skills to make
their study more attainable. To better understand their study and findings, it is important to know that they defined critical thinking as, “an operative example of higher-order thinking that can be accounted for due to reliable and validated tests” (Miri et al., 2007, p. 355). Miri and his colleagues found that student’s self-confidence increased with their continued practice in critical thinking skills and practices. They also noted that the students matured over the course of the time in their study which made a difference in their decision-making skills. “Moreover, teaching for enhancing higher-order thinking skills promoted students’ ability to assess information (Evaluation) as well as, the ability to identify and secure information needed to draw conclusions (Inference)” (Miri et al., 2007, p. 361). Miri and his colleagues’ study showed how if we change our teaching pedagogy to challenge students in new ways, there will be an increase in their ability to think deeper and critically interpret the world around them.

As noted previously, there is more research based on higher-order thinking skills and inquiry in secondary and collegiate education. In 2013, a college in Israel created a research study in which freshman biology and chemistry majors experienced biology through an inquiry approach that promoted higher-order thinking skills (Hugerat et al., 2014). Ultimately, the study found that having an inquiry-based teaching approach had a large impact on students’ higher-order thinking skills among the study participants (Hugerat et al., 2014). “Also, the students expressed a positive attitude, both emotionally and cognitively as a result of the intervention” (Hugerat et al., 2014, p. 447). This is important because the students’ feelings and beliefs towards a subject can determine how
they engage with that material in the future and if they’ll continue to pursue a higher education or career in the field.

Students’ experiences in science can cause them to look and think critically about the world around them. This happens within inquiry-based science due to the integration of having authentic assignments in which higher-order thinking skills and collaboration are needed in order to be successful. A study that takes a closer look at this was done by Mahoney in Australia. He studied the effects of collaborative test taking and curiosity surrounding if students’ higher-order thinking skills would increase more during this kind of practice rather than individual testing. They hypothesized that students would perform better on higher-order thinking questions within the exam and that they would receive a higher score overall. In this study, undergraduate students completed an individual assessment, which was then followed by a collaborative test (Mahoney et al., 2019). The study found that except for students that were outliers and did extremely well on the individual exam, most students scored higher on the collaborative exam (Mahoney et al., 2019). “Additionally, regardless of their academic abilities, students performed better on the higher-order thinking questions under collaborative conditions. This improvement was equal across different academic abilities, suggesting that collaborative testing promotes higher-order thinking even when considering previous academic achievement” (Mahoney et al., 2019, p. 25). This study causes educators to think that if our end goal is to promote higher-order thinking skills, we might need to revise the way in which we assess our students' learning as well.
Inquiry-Based Science and Cooperative Learning

Depending on a preservice or current teacher’s experience learning about inquiry-based science, their thoughts, beliefs, and actions towards it can be different. Amirshokoohi et al. (2013) noted that, “Science is socially constructed and so is students’ knowledge of science concepts; therefore, it is vital to focus on the often-neglected dynamics of this social learning process and students’ experiences and interactions in such collaborative learning contexts” (p. 145). After conducting a study where preservice elementary teachers were able to learn about and experience inquiry-based science instruction the findings were overwhelmingly successful. Some of the comments after they completed their lesson was that they experienced the information in a more authentic format, it allowed them to see that science is not a linear process, and that working as a community of scientists was something all benefited and appreciated (Amirshokoohi et al., 2013). One preservice teacher noted about the experience, “My group first thought the scenario was weird, but it really helped me see how science is done. Scientists don’t just work individually in their labs” (Amirshokoohi et al., 2013, p. 148). This is an important point and emphasizes that while learning and doing science lessons, students are doing more than just learning about the content. They are creating a research question, taking observations, gathering data, discussing their ideas with their peers, co-constructing meaning, coming to a conclusion, and then sharing out this information with other small groups within the class so that everyone is able to learn from their findings.
Additional Skills Taught in Inquiry Language Development.

When students are posed a problem or a research question and need to investigate in order to come to further conclusions, they’re working on growth in other social skill sets alongside the scientific experience. Students are learning how to communicate effectively in small groups and think creatively together to try to achieve the best possible outcome. For them to be successful, they have to further develop their language skills because they’re going to be communicating about the research question, the investigation that they’re going to execute, their observations, and their findings among their group members. At the end of their investigation, students will also share out to the whole class what their small group investigated and what their findings were alongside support from their research such as science notebook entries, photos, drawings, and so forth.

In San Francisco, there is a museum called the Exploratorium, with over 650 interactive science exhibits such as, “dance with your own shadow, levitate, touch a tornado, mix colors and break light apart, stop time, start a conversation, capture a wave, and many more” (“Science Talk”, 2016, para 1). The Exploratorium website (2016) discussed the importance of “science talk” and how when people are involved in inquiry-based science, they are wondering about a research question that they have posed and are having conversations with others about their discoveries. They encouraged the practice of creating guidelines or norms before having an inquiry-based science lesson, because then all of your students will feel respected. This would also be a part of building your classroom community at the beginning of the year, but you could talk about prior
guidelines and how they're different or similar when you’re working with small groups during science.

The Exploratorium Museum noted that having discussions is a huge part of science because people discuss possible research questions, experiment approaches, methods, observations, data, conclusions, and building connections with each other’s thoughts (“Science Talk”, 2016, para 2). While students and teachers have discussions with each other, they are developing both their science knowledge and language development. This is particularly beneficial to students who are English Language Learners because they are given the opportunity to practice using new academic language and their second language as well (“Science Talk”, 2016, para 3). When English Learners (ELs) are participating in science inquiry lessons there can be many different parts of language development opportunities that will happen such as listening, participating in everyday language, participating and practicing with academic and scientific language (“Science Talk”, 2016, para 5). An important practice to emphasize with your students is, “students are encouraged and allowed to use the type of language that is accessible to them in order to fully support the expressions of their ideas” (“Science Talk”, 2016, para 5). This is crucial for success in your science lesson plans because your students may know what they want to say in their home language and not be able to express themselves as they’d like in their second language or in English. Educators can scaffold the material and make accommodations for students as they see needed in order for the lesson to be accessible to everyone in their classroom. The Exploratorium Museum’s website stated that, “The ultimate goal of science talk is to create a discourse-rich classroom culture
where the natural synergy between language and meaning making supports all students in expressing ideas, developing language and acquiring new knowledge of scientific phenomena” (2016, para 4). The interdisciplinary connections between language, other people’s perspectives and science is important because it illustrates that inquiry-based science has many key components that work in conjunction with each other in order for it to be successful and carried out to its fullest potential.

**Incorporating Writing into Inquiry-Based Science**

Another important aspect of inquiry-based science is writing. Students will write their ideas for proposed research questions, collect data during their observations, write about their findings, and reflect upon the process. Dotger and Glen (2013) conducted a study looking into how elementary school teachers understand and use writing in their science class. Teachers’ prior knowledge confirmed that they would use writing in the, “presentation of data, observations, experiences, procedures, and facts” (p. 957). Teachers then used writing in these ways within their lessons. Dotger and Glen (2013) proposed that teachers could also extend writing in their science lessons by, “providing teachers with better models for how and why scientists write, including these models in more inquiry-based science lessons, and directly relating concepts of nature of science to elementary science writing” (p. 957). Giving teachers more information about how scientists use writing in their own lives would help create more authentic writing experiences for their students. It would give them a chance to see what and how real scientists investigate data, conduct research, and write about their own findings.
The inquiry-based pedagogy provides a new approach for how educators can teach science to their students. It causes the lessons to be more student-led and interactive compared to the prior traditional approach to teaching the content with rote memorization and summative written assessments. Due to the nature of this approach, it causes students to use higher-order thinking skills compared to lower-order thinking skills. Some of these are analysis, synthesis, and evaluation. Students are also thinking more critically about the content than before due to the investigative manner of this pedagogy. Language development and critical literacy are also skills that can be taught in inquiry-based science lessons. Providing our students with opportunities to work more deeply with the content and problem solve at a higher level like what they’ll need to do in the work or educational world after school helps set them up for a more successful future.

Phenomena-Based Science Instruction

About Phenomena. NGSS has a list of resources on their website that can be helpful to teachers. One of these resources is a video that Teaching Channel created about Phenomena. In this video, they describe phenomena as, “a way to make science accessible to all students and compel students to want to figure something out” (NGSS EQuIP Rubric: Using Phenomena, 2018). They framed their video with the statement of “Using Phenomena to Engage Students in Science”. In the video, Henriques defined phenomena as “something that is engaging and really hooks students’ interests” (as cited in NGSS EQuIP Rubric: Using Phenomena, 2018). She went on to state that it can be related to an event in isolation, an everyday experience, a current event, or a video that makes the students ask questions (NGSS EQuIP Rubric: Using Phenomena, 2018).
Phenomena can flow through the entire unit; it can begin the unit and reference back to it as we investigate further with our students. It is important to consider if the phenomena are interesting to all students and not just one particular group of students. Finding good phenomena for lessons can be difficult because it can’t just be engaging and cause wonder in our students, it also has to assist them in learning in a purposeful way (NGSS EQuIP Rubric: Using Phenomena, 2018). This goes back to the three-dimensional learning that the NGSS Standards are emphasizing to be a part of the new curriculum and learning process. Henriques stated that, “The importance of having a phenomenon that relates to all the students in the classroom is an equity issue. It helps level the playing field” (NGSS EQuIP Rubric: Using Phenomena, 2018). Using phenomena in science education is a natural fit because all people are curious about the world around them and how the world works, especially in the context of things that relate to their everyday lives (NGSS EQuIP Rubric: Using Phenomena, 2018). Students will see a purpose for science and want to engage in this process when we combine inquiry and phenomena with our new NGSS Standards. It will be far more relevant to them and their world. Any time we can relate content to our students’ everyday life they are going to be more engaged because they identify with what we’re learning (NGSS EQuIP Rubric: Using Phenomena, 2018).

A NGSS guide describes natural phenomena as, “observable events that occur in the universe and that we can use our scientific knowledge to explain or predict. The goal of building knowledge in science is to develop general ideas, based on evidence, that can explain and predict phenomena” (“Using Phenomena in NGSS Designed Lessons and
Units”, 2016, para 1). If we think of these new standards as STEM based, we can connect engineering because it, “involves designing solutions to problems that arise from phenomena and using explanations of phenomena to design solutions” (“Using Phenomena in NGSS Designed Lessons and Units”, 2016, para 2). Phenomena is a piece of science education that has previously been missing because we’ve focused teaching general knowledge to our students rather than closely examining and exploring the real world around us (“Using Phenomena in NGSS Designed Lessons and Units”, 2016).

**Anchoring and Lesson Level Phenomena**

McKenna, a staff scientist for the Connecticut Science Center and Charles H. Barrows STEM Academy described two different levels of phenomena, “An anchoring phenomenon requires an entire unit for students to be able to explain the science behind it, whereas smaller, lesson-level phenomena help students figure out smaller pieces of the larger picture” (as cited in Maltese, 2019, para 2). Another interesting fact is that any phenomena can be used across all grade levels K-12 and you can cater it to your students’ needs and what they’re learning about in their science class based on the NGSS that their class is currently covering.

As educators dive deeper into this work, supporting materials and information are essential to creating a clear understanding of concepts and exemplars that we can build upon. Penuel and Bell created an informative handout that is available on NGSS’s website. It outlines how to know if a phenomenon is well suited for a sequence of science lessons. Some characteristics to look for when choosing phenomena to match to standards are that it builds upon every day or family experiences, is interdisciplinary, is
too complex to understand after a single lesson, is observable to students, has relevant data, images and text to engage students, and has an audience or community who cares about the findings or products (Penuel et al., 2016). An example of this is conducting an experiment with balloons lying flat on a table. If you squeeze an orange peel over a balloon, it pops! This generates curiosity and one would further explore what is in an orange rind, what chemicals are involved in this reaction, and look closer at students’ observations to guide discussion and investigation (McKenna, “Phenomena for NGSS”).

Summary

In conclusion, inquiry-based science is a pedagogical approach that can lead elementary students to develop more critical thinking, higher-order thinking skills, and problem-solving strategies. In order for this implementation to be the most successful, teachers will need to become facilitators in their classrooms compared to the more traditional approach where the teacher is a wealth of knowledge at the front of the classroom. Next Generation Science Standards are being created to engage students in everyday phenomena and science more than ever before. Giving students the opportunity to explore topics of interest to them in a hands-on manner will allow them to act and think like a scientist. While there are some concerns about implementing these new standards such as equitable allocation of resources, we can focus on what we can control which is pedagogical approaches that will change our students’ experiences for the better. Including natural phenomena will hook our students’ interests and cause them to have a mindset of wondering about the world around them and creating a desire to learn more.

This research has led me to my research question: How can curriculum design in upper
elementary science education enlist students in practice and demonstration of higher-order thinking skills? I want to see how designing and teaching inquiry units can further students’ higher order thinking skills of synthesis and evaluation. Especially with the new change of Next Generation Science Standards in which our pedagogical approach must be examined and altered.

In Chapter 3, I will discuss the details of learning about my research question and how that will continue to shape my capstone project moving forward. Chapter 3 will also have the methods for my capstone project and will discuss those details further. It will discuss the curriculum that I will be developing and what theory is behind the purpose of my creation. Chapter 3 will also describe the implementation plan of my inquiry-based curriculum and how I plan to gather data on how students’ higher-order thinking skills are increased and grow when this type of pedagogy is in place.
CHAPTER THREE

PROJECT DESCRIPTION

Introduction and Rationale

As I have become more involved in elementary education and teaching its different content areas, I have been intrigued by the subject of science. As a student, I was not very involved in the sciences. During graduate school, I learned that it is a subject that can teach students and teachers to be curious about the world around them and to be scientists themselves. I have found that students and teachers alike can be creative in the sciences, which is more appealing to me seeing as I enjoyed art and English more due to the answers of these subjects being varied compared to a specific answer in an upper science course or mathematics.

After developing this newfound love for science, I have been left wondering what is the best way to teach this content to our students? I have had the advantage of working at a few different districts and schools, therefore I have seen a few different things done. Now that I have a classroom of my own, I am left contemplating what pedagogy will give my students the most transferable skills that they need? During my research project, I am asking, How can curriculum design in upper elementary science education enlist students in practice and demonstration of higher-order thinking skills? I want to see how designing and teaching inquiry units can further students’ higher-order thinking skills of synthesis and evaluation. I am designing a fourth-grade science unit where students are studying erosion and the different ways it impacts the Earth’s surface.
Overview of the Project

In preparing my students to be informed and active citizens, I have studied how inquiry-based learning in upper elementary science instruction can improve students’ higher-order thinking skills. They will need to utilize higher-order thinking skills in order to think critically and take in information from the world around them both inside and outside of educational settings. Within my capstone project, I am going to focus on the higher-order thinking skills of synthesis (inferring relationships among sources) and evaluation (students making judgments about the value of ideas, items, and materials). I chose synthesis and evaluation because I believe that they are important skills that can be transferred across other content areas and contexts of everyday life. I think that if students felt more comfortable with looking at information in conversation with other sources, they could come to more profound thoughts over the course of their educational career.

For my capstone project, I have designed an inquiry-based science curriculum that is for students in fourth grade. This could be adapted to work with third and fifth graders as well. It would change slightly depending on the different content standards that each grade level has, despite its overarching themes. I have created a unit on erosion for my students that will last the duration of two school weeks or ten lessons in its entirety. I currently teach fourth-grade science, therefore giving me that specification and making this project have a stronger purpose.
Audience

One audience for this science is my current students. I co-teach science to a fourth grade class of thirty students. There are high needs as far as language learners go and struggling with the academic language within upper elementary science. There are also a large number of students with special education services in this class which presents itself with another set of challenges. Another audience is to other educators who can use this unit as is or for a guide to create inquiry-based lessons that cause students to use higher-order thinking skills. The curriculum is inquiry-based and student-centered which provides students with a chance to dig deeper into the content and engage with the material in new ways. inquiry-based pedagogy can be intimidating to teachers because we leave some of the learning and where we go with the content up to the students. This is also why it can lead us to discover newer and deeper learning than a traditional curriculum could provide us with.

Theoretical Framework

I have based my capstone project from the theoretical framework of inquiry-based science. “Inquiry-based science adopts an investigative approach to teaching and learning where students are provided with opportunities to investigate a problem, search for possible solutions, make observations, ask questions, test out ideas, and think creatively and use their intuition” (Bulba, 2019, para 3). This pedagogical approach gives students a hands-on experience with science that causes them to use higher-order thinking skills and problem solving, rather than textbook reading assignments and rote memorization that can be seen in a more traditional pedagogy.
Inquiry-based science instruction emerges out of social constructivist perspectives on learning, which emphasize the idea that knowledge is actively constructed by the learner, in contrast to being transmitted directly from the teacher to the learner (Akuma et al., 2018, p. 65). Giving students the opportunity to build upon each other’s prior knowledge and make new connections will help them gain a fuller understanding of the content and help them remember it better in the future. When students make neurological connections from the past to new knowledge, it is more meaningful and easier to remember compared to taking in the new information in isolation. For inquiry to be successful, teachers must “recognize the importance of presenting problems to students that will challenge their current conceptual understandings, so they are forced to reconcile anomalous thinking and construct new understandings” (Bulba, 2019, para 3). In doing so, the teacher must give up a lot of their control in the classroom and become a facilitator compared to the one source of knowledge that leads the classroom through a sequential set of steps. Their goal in inquiry-based teaching is to be guiding students, helping them understand what they are researching or finding, and providing detailed feedback.

**Curriculum Writing Framework**

Inquiry-based science and higher-order thinking skills are the two core concepts of my work within my Capstone Project. As far as curriculum goes, I have looked closely at Amplify Science Curriculum and Erosion. I also taught a similar unit to my fifth graders during student teaching last year with a Foss Kit. Therefore, I am going to take the best pieces of these two curriculums and make them more inquiry-based. “Amplify
Science blends hands-on investigations, literacy-rich activities, and interactive digital tools to empower students to think, read, write, and argue like real scientists and engineers” (Amplify, 2019, para 1). Amplify’s Science curriculum is rooted in research from Lawrence Hall of Science’s Do, Talk, Read, Write, Visualize model of learning. The curriculum allows students to explore the content in different ways that highlight different learning styles. This allows them to receive a higher quality science education. With this curriculum, there are books, investigation notebooks, simulation and practice tools, teacher materials, and material kits. With all of these supplies, the students will be working as scientists and engineers to discover science through phenomena and inquiry-based investigations.

I have also looked at Grant Wiggins and Jay McTighe’s curriculum design that is outlined in their book titled, *Understanding by Design* (2005). In this book, Wiggins and McTighe focused on looking at the learning goals of the lesson planning first. Then, they move to assessment and look at what strategies they need in order to achieve the learning goals. Traditionally, curriculum is written in a forward’s manner from everyday lesson activities to pedagogy and then moves to different types of assessment and learning targets. Wiggins and McTighe argued that their focus on learning goals and overarching themes and strategies needed for the unit brings a deeper and more strategic approach to curriculum creation.

**Setting and Participants**

I will teach my Science Unit at a charter school serving grades K-4. I work with a class of thirty 4th grade students and my co-teacher. The students at this school are from
diverse ethnic groups. The highest percentages of students are Hispanic/Latino or African American descent. There are 296 students enrolled at this school. Seventy-five percent of the students are English Language Learners. Eighty-eight percent of the students are on free and reduced lunch services. Twelve percent of the students receive special education services. The school community is driven to close the opportunity gap, provide an equitable education where all students receive a high-quality education which prepares them to be college ready after graduating and serve the common good. The intended audience will be my colleagues, the school community trying to close the opportunity gap, and anyone interested in inquiry-based science curriculum for this age-level that targets higher-order thinking.

My project will be complete at the end of the Spring 2020 semester. I have 14 flex days in my science class in which my co-teacher and I need to fill. I would like to use these flex days as an opportunity to use my curriculum and then have a few days to review content for their exam. I finished my capstone project draft by April 5th. Afterward, I wrote a reflection chapter and also spent time presenting my research and project to my colleagues during April and early May.

**Assessment**

The effectiveness of my project will be demonstrated once I have taught my science unit with a classroom of students. At this point in time, I will be able to see how the students have done on the performance tasks. These tasks are the newer form of assessment in which students are asked to put their knowledge to the test and problem solve. In my science unit, this will be seen in the flood barrier challenge and the public
service announcement poster. Both of these will be graded with a rubric which includes the higher order thinking skills of synthesis and evaluation. It will be beneficial to see how the students perform with a small group (for the flood barrier performance task) as well as on an individual basis. On a more formative assessment note, I will know that my project has been successful if students are engaged in higher order thinking skills and questioning throughout my lessons and investigations. I will know if it is successful if I see students engaging deeper in scientific academic language than compared to before. I will also know if it is successful if I see my students pushing themselves to think deeper about science and problem solving as they analyze and evaluate our investigations.

Summary

In conclusion, I have created a science unit with an inquiry-based pedagogy that requires students to have opportunities to develop their higher-order thinking skills. This will be written for a fourth grade science class. I decided to do one strong unit rather than more because I have the ability to focus and have a strong set of lesson plans. This type of teaching and use of higher-order thinking skills of synthesis and evaluation will research if students are indeed growing and using these skills more than previously due to the alteration of pedagogy.

Chapter Four is a critical reflection on the creation of my project. I will discuss my major learnings as both a researcher and teacher. I will also discuss if the major learnings were expected or not. I will revisit my literature review and see what research proved to be most influential in my project along with any new connections that have been made. Limitations of my science unit that I created will be examined. Future
research and how I will be communicating my results will be reviewed as well as my project’s benefit to the profession of upper elementary science instruction.
CHAPTER FOUR

Critical Reflection

Introduction

During my experience as an educator, I have found myself looking at the way we teach our content through a critical lens. While there are many different approaches, I think it is important to consider what end of unit goals there are for the students beyond content mastery. As I have looked deeper into this, I have found myself questioning if the students are learning to have a sense of wonder and learning to be inquisitive about the world around them. This thought has brought me to question, how do the students benefit from a student-centered curriculum in which they are the agents of their learning? This is what led me to consider what higher-order thinking skills can students develop through inquiry-based learning.

I have been fascinated with inquiry-based learning since hearing about it in my graduate school courses because it is so opposite of my personal experience as a student. I went to public schools for my entire K-12 education and had mostly a traditional, teacher-centered approach to learning. I was someone who, despite the style of instruction, loved learning and found ways to engage in the content. I want to ensure that my students have more opportunities to investigate and evaluate the content that we are working with in science and give them space to find new connections and conclusions. Therefore, for my research question I have asked: How can curriculum design in upper elementary science education enlist students in practice and demonstration of
higher-order thinking skills? I want to see how designing and teaching inquiry units can further students’ higher-order thinking skills of synthesis and evaluation. I chose these skills because I think that they are transferable to other content areas and everyday life as well.

In this chapter, I will reflect on my major learnings throughout the capstone project process, and revisit my literature review to see what research proved to be most influential to my project. I discuss the limitations and implications of my project. I will also consider what future research projects and areas of interest this has developed for myself and for others to look into. I will share how my project will reach others teaching upper elementary science and how my project benefits the professions of upper elementary science.

Major Learnings

Throughout the duration of my capstone project, I have learned many things. As a researcher, I have learned that things are always changing and evolving. I have noticed this especially in the field of science and in research surrounding education as well. The timeline of when I wrote the beginning of my project and when I wrote my final portion of the project was only a semester apart, yet it felt like there had been more time in between. There began to be a bigger emphasis on phenomena based science education and inquiry-based seemed to be tied up in this new idea. I think that they are related and go together well. I am happy that I chose to focus on inquiry-based teaching because I would like for my pedagogy to become more student-centered.
As a writer, I have learned that scientific writing is a whole new type of writing that I have not been exposed to much before this capstone thesis project. During my undergraduate studies, I majored in English Literature. I felt that I had a good handle on academic writing then and have improved it during my time in graduate school. Little did I know that a whole new type of citations American Psychological Association (APA) versus my previously known citation model of Modern Language Association (MLA). This has been a learning curve, but I am feeling that I understand it better now which is exciting. I found the literature review particularly hard to write because it was so dense compared to my previous writing types of essays and persuading a reader to see your perspective on a certain character, motif, or theme in a book. I am thankful that I was able to take the beginning portion of this thesis project in the summer so that writing had my full attention with less distractions such as work. I have learned that with creating a capstone thesis project, some of your work is evolving as you go. I particularly noticed this with Chapter 3, which was an overview of your project. When I was originally writing this last summer, I was uncertain of exactly the path that I would go on but knew where I would like to get in general of writing a unit of instruction for upper elementary science. As I began to dive deeper into this process and complete the second portion of my project, my end goal became more clear and I was able to redefine my project with more detail.

As a teacher, I think that it is important for you to reflect and take time to learn from your experiences. I have learned through this process that it ended up being a better fit for my project to work with the base knowledge from FOSS Kits rather than my
school’s curriculum of *Amplify*. I say this because, *Amplify* is more scripted and has a plethora of activities. In my experience using it at school, we never complete all of them in a unit and try to take the more hands-on activities, leaving some of the teacher centered ones behind. Originally I was thinking of taking the best of these two units of erosion and combining them with my own ideas to make my unit. This turned out to be too much. There was not much wiggle room for new ideas and I did not want to randomly throw some neat virtual models in there when I had not used any of their information before. After teaching *Amplify* to my fourth-grade students, I also learned that it is written in a way that they assume your students have scientific academic language and have taken science throughout all of their elementary school years. This was not the case for my students, seeing as we just started using this curriculum this year. Almost all of my student population have English as their second language and Spanish as their first. This became a hurdle that myself and my co-teacher were constantly up against, trying to modify and have the necessary support so that all of our students were able to access the content that we were teaching. Therefore, this led me to focus on my previous experience with FOSS kits and have more room to expand and make it inquiry-based as I had imagined.

While most of these learnings were expected, there were still some that came by surprise. I had expected that writing a capstone with research would be difficult and new to me. I knew that the capstone project would challenge myself in all aspects of being a researcher, writer, and learner. I did not expect that taking a semester off to begin my first year of teaching would feel like so long between capstone courses. I am glad that I did
not take off any longer and was able to complete the capstone project in my personal timeline of an academic year. It was unexpected that trying to find the right base of knowledge and pieces of a curriculum to build upon would be so tricky. I am sure this also comes from as my thesis became more detailed, I knew where I wanted to go with my project and wanted to ensure I had room to do so.

**Literature Review Revisited**

One of the most important pieces of my literature review is the information surrounding the Next Generation Science Standards. These new science standards have taken science instruction to a new level through having multi-dimensional learning. The three dimensions are the science practices, disciplinary core ideas, cross cutting concepts (NGSS, 2020, “Understanding the Standards”). The NGSS Standards have performance expectations that require students to engage in the material with all 3 dimensions at the end of the unit to grasp their mastery of the content (NGSS, 2020, “Understanding the Standards”).

Another study that was influential for my project was Anderson et al. (2018) because they took a critical look at how these new standards would call for instruction reform within science classrooms. Anderson et. al. stated, “Students should use crosscutting concepts and disciplinary core ideas as they engage in scientific practices focused on phenomena in the material world” (p. 1027). Anderson et. al. brought up a valid point when saying that most classrooms do not provide this experience for our students as of now (p. 1028). Students create projects and assignments in return for a grade. Anderson et. al. also shared the concern of how to make this change in curriculum
an equitable one with the topic of access to resources (2018, p. 1028). Due to the way we currently fund our schools those in higher income property tax areas will be able to make this switch easily and those who have low income property taxes will struggle to gain access to the things they need to teach their students in this new way (Anderson et. al., 2018, p. 1042).

Another article that was most influential in my research was written by Bulba (2019), of the Smithsonian Science Education Center discussing inquiry-based science. Bulba stated that, “Inquiry-based science adopts an investigative approach to teaching and learning where students are provided with opportunities to investigate a problem, search for possible solutions, make observations, ask questions, test out ideas, and think creatively and use their intuition” (para 1). This pedagogical approach gives students a hands-on experience with science that causes them to use higher-order thinking skills and problem solving, rather than textbook reading assignments and rote memorization that can be seen in a more traditional pedagogy. I had been very interested in inquiry-based teaching prior to beginning my research, but as I began to learn more, I could not help but wonder what benefits students who received this type of instruction had gotten. With Bulba’s mention of higher-order thinking skills, this sent me on my research question and gave me more momentum for my thesis project.

New Connections

After working in an urban school this year compared to a suburb school last year, I have had a chance to see these equitable issues first hand. The suburb school had their curriculum, lots of resources, technology for every student, books for every student, and
so forth. The urban school that I teach at now has two or three carts of chromebooks that we alternate grades using at certain times of the day. The class sizes are so large that the number of paper copies of resource books used in the lessons in the curriculum does not cover all of the students in our class. Students pair up and work together just fine but there is a difference that is present in all aspects of the educational experience. The school that I currently work at does not have homework for specialist courses because students have other responsibilities to tend to once they go home. Students at the suburban school received homework in specials if they did not finish their work within the time given, which meant that they were not taking the task seriously at that time. It is important to take these facts into consideration when calling for reform of a content area because it impacts how we teach in a great way.

Limitations

Although the previous paragraph stated access to resources, my current school is able to plan and share them so that all upper elementary grades are able to receive what they need for their science curriculum and education. This is important in saying because I plan to implement this unit at the same school next year. Due to the current Coronavirus situation, our school purchased devices for each student so that they are able to access education through distance learning. This could have been a limitation in the future if our current situation was different.

A limitation for others who may use this science unit is that it incorporates the FOSS kits which is a curriculum that you have to pay in order to access their content. I included Google classroom as a part of my lessons but you could print out paper packets
and do work that way as well. One of the performance tasks that I chose was from a Teachers Pay Teachers purchase which cost money. With the current economic climate, I am more aware of these barriers that may affect how and when my science unit is used by other educators.

**Future Research and Projects**

I would recommend future research and projects to follow students who have had this curriculum change into secondary schooling. I would be interested to see how these students’ higher-order thinking skills have developed and can be shown in the cross cutting science dimensions of standards but also across content areas. In secondary school, even in middle school I feel as though you can get more detailed in what you are teaching your students and asking of them and it would be interesting to see how far you could push them as far as their critical thinking skills go. I would also be curious to see what research could be done on phenomena based learning and how that impacts students’ critical thinking and how that knowledge has been transferred into real world problems (possibly for high school students). I think there is so much that could be done within science and the application of higher-order thinking skills, and phenomena based education.

**Communicating Results**

I will share my results with my current school and district because I will be implementing them next year in our science class for fourth graders. I will be sharing it with them in one of our professional development sessions. Since my capstone project is related to what I taught in fifth grade I will share it with my previous cooperating teacher.
and her colleagues upon completion of this course through email due to the current pandemic situation and stay at home order. I plan on sharing it with different teacher friends from graduate school who are involved in the same grade range of 3rd to 5th grades or teach in the subject of science.

**Benefit to the Profession**

My capstone project benefits the field of education because it takes a critical look at the pedagogy we use surrounding teaching science in upper elementary education. It is important to look closely at our practice and reflect in order to grow. The new standards will also make us do this but it is important to continue to do so that we can continue to grow as educators. I think that striving towards a more equitable education system and having rigorous content and high engagement for our students is crucial to their success. I would argue that my project strives for these standards and that future research can be done in order to make more progress towards that goal.

**Summary**

In conclusion, I have learned many things throughout the capstone project process. I have learned that things are constantly changing and evolving. This applies to both the science content, how we teach our students, and the different ways we address the inequities within the education system. I have gratitude for learning a new type of academic writing, which is research and a new way of citing my findings. I have learned that sometimes a less scripted base for curriculum can leave room for critical thinking practice. Educators can plan questions to pose to students and different ways to interact with them to instill curiosity in the students about the world around them. I have learned
that equity is a much larger problem in education than I had previously thought and I know that there is still a lot of work to be done there. I am grateful to be a part of the movement towards all students being equipped to serve the common good and graduate from college.
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