The Declining Role of Elementary Science Education in the United States:

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The Declining Role of Elementary Science Education in the United States:
A Professional Development Series to Provide Instruction on Nature of Science, Inquiry, and
High-Level Inquiry Questioning for Elementary Teachers.

By
Amy Lynn Visca
December 2014

A culminating project submitted to the Department of Education and Human Development of The College at Brockport, State University of New York in partial fulfillment of the requirements for the degree of Master of Science in Education
The Declining Role of Elementary Science Education in the United States:

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High-Level Inquiry Questioning for Elementary Teachers.

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APPROVED BY:

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Advisor                                           Date

__________________________________________  ____________________________
Chairperson, Education and Human Development      Date
Abstract

Nationally, the most important goal of contemporary science education is to produce scientifically literate adults (Zimmerman, 2007). The current goal of the National Framework for K-12 science education, which is to ensure that by the end of 12th grade, all students have some appreciation of the beauty and wonder of science. This includes their ability to possess sufficient knowledge of science and engineering information to adequately engage in public discussions on related issues. These abilities will increase in time with a goal of creating a student body that is able to continue to learn about science outside school. Further, it strives to create students who are careful consumers of scientific and technology. Most importantly, the framework strives to ensure that American students have the required skills to enter careers of their choice, including (but not limited to) careers in science, engineering, and technology (U.S. Department of Education, 2008). These goals are meant to hold true in elementary schools as well as it is here that children receive their initial experience of formal science education. They are taught, by selection of national and state curriculum, what matters in the world and how to deepen their understanding of concepts presented. Despite the goals and intent of elementary science education, the role of science in elementary grades has been declining steadily in the United States according to some national and private research.

Meaningful science education reaches beyond the science classroom as the thinking skills used to understand science can be related to other formal and informal thinking skills (Kuhn, 2002). Currently, recent efforts to reform and improve the way science is taught strives to make certain that those who do not pursue a career in science are able benefit from the basic thinking skills taught in the classroom (Ford & Forman, 2006; Metz, 2004; O'Neill & Polman, 2004). By focusing on interventions that encourage the development and practice of investigation and inference skills, science education will become increasingly relevant to the needs of all students (Zimmerman, 2007).

Despite current efforts and the conceived notions of the importance of science, the role of elementary science education and its effectiveness is declining in the United States. A host of research suggests that science education should be centered around inquiry-based learning. A central issue of elementary science education is that inquiry and Nature of Science education is not present in the curricula of most elementary science teachers'
personal education. To remedy this issue, it has been found that appropriate pre and in-serve science education in the form of professional developments can increase a teacher’s ability to effectively teach elementary science.
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Chapter I

Rationale

This thesis serves to identify some of the potential issues in elementary science education as well as to present a solution in the form of a Professional Development that can be used by school districts to enhance their current elementary science education programs. The professional development and teacher education described in this work would best be utilized by a district Science Coordinator. The main items of interest in this project include:

1. Research surrounding the decline in elementary science education.
2. Best-practice elementary science teaching methods (Inquiry).
4. Research surrounding the importance of professional development for elementary teachers, specifically in regards to elementary science.

The need for this project within the elementary science and educational community is significant. First, research conducted by Milner, et al (2012) indicates found that teachers’ actual beliefs regarding the importance of science rested largely on peer and administration perceptions of the importance of science teaching. Next, Milner (2012) conducted a survey of elementary teachers that reviewed their perception about the importance of teaching science before the NCLB Act was conducted. Importantly, a number of teachers felt that state pressures to teach mathematics and reading discouraged the teaching of science; however, it was also found that the perception of others largely affected their views of the importance of teaching science (Milner, et al. 2012). Simply stated, the general perceptions regarding science of the colleagues, administrators and districts where a teacher is employed seems to hold greater merit than NCLB or other pressures and perceptions regarding science education. The importance of science can therefore be thought of as specific to a school or district, rather than any other measure. Of course, to come full circle, the specific school and district opinions and perception of the importance of teaching science are likely influenced by all media, national efforts, and research regarding science in education. In sum, if a district were convey the importance of science through
discussion and professional development reinforcement, teachers would feel as though science is more important.

Secondly, student needs in science are not always identified during the course of an electuary teachers’ personal education. This makes the need for professional development critical for student success in science. Specifically, teachers need to understand the importance of inquiry-based instruction. Inquiry is defined as a set of interrelated processes by which students pose questions about the natural world and investigate phenomena (National Research Council, 2000). When students learn science in this matter, students are better able to understand the concepts, principles, models and theories associated with scientific literacy. The theory behind utilizing this method is so students have the opportunity to learn science in a way that reflects how science actually works in the real world. Fostering this understanding will allow students to achieve greater science literacy.

Overall, this project can allow both teachers and administrators to better understand proper science teaching methods to increase the success of their current science programs. The professional development is created with the needs of elementary teachers in mind, as specific by current research, and will serve as formal education in the area of elementary science education. To further enhance the professional development, a single unit has also been created as an example for teachers to utilize that encompasses the idea ideas of inquiry-based instruction in the elementary classroom.
Significance of Project

The purpose of this project is to demonstrate effective guidelines to creating and implementing a successful science curriculum for use in elementary education. This complete unit, along with the support of a Science Coordinator, will serve to:

a. Allow teachers to better understand inquiry, the nature of science and, more importantly, their significance in elementary science instruction.

b. Provide teachers with effective lessons that will relate across multiple years of science education in an organized fashion while adhering to Common Core Standards.
   a. Provide students an opportunity to utilize critical thinking skills.
   b. Provide students an opportunity to experience inquiry
   c. Provide students an opportunity to develop a bond with science through engaging and meaningful lessons that will inspire a desire to further their understanding of concepts.

c. Provide school districts with a tool that is malleable to changing needs while providing a consistent education across all elementary classrooms with the goal of a more centralized collection of knowledge for secondary science education.

The intent for this project would be for a district Science Coordinator to implement its content throughout elementary schools. The Science Coordinator would provide pre and in-service training which would include: (1) education on the Nature of Science; (2) instruction on how to complete inquiry-based lessons; (3) provide a Smart Board presentation for teachers to utilize that correlates with the lesson plan outlines and discussed in the Professional Development, and; (3) ongoing support and communication throughout the school year for classroom teachers.
Overview of Chapters II and III

Chapter II includes a review of the literature surrounding several facets of elementary education. First, research is presented that looks into the potential underlying causes for a decline in elementary science education in the United States. Next, we examine the needs of elementary teachers, which include a better understanding of the nature of science as well as a better understanding of what inquiry-based instruction is and how to use unit properly in their classrooms. Several misconceptions regarding the use of inquiry from both teachers and students is included to encompass a variety of viewpoints and allow for thoughtful consideration of how to remediate the misconceptions. Last, research surrounding the positive impacts and importance of professional development across a teacher’s career is presented.

Chapter III includes original work that serves as remediation for the issues and suggestions discussed in chapters I and II. A one hour long professional development is included in the form of: (1) An agenda of the professional development; (2) the teacher handout used during the professional development; (3) The slides to an attached Power Point presentation that coincides directly with the handout. Next, an original inquiry-based sample unit to be used in the classroom by teachers who have completed the professional development is included as well as a reflection worksheet to be utilized by teachers after teaching each lesson.
Definition of Terms

CONSTRUCTIVIST LEARNING: A learning theory based on the idea that students construct their own learning through meaningful activities.

CRITICAL THINKING: The intellectually disciplined process of actively and skillfully conceptualizing, applying, analyzing, synthesizing, and/or evaluating information gathered from, or generated by, observation, experience, reflection, reasoning, or communication, as a guide to belief and action.

INVESTGATIVE PRACTICE: A method of solving an issue (or science concept) using various investigative techniques and deductive reasoning.

INVESTIGATIVE CULTURE: An environment where investigative practice (above) can thrive.

LABORATORY: An exercise in a science classroom where students are involved in activities that allow them to develop science skills such as collecting data, making observations, and where they are manipulating factors that demonstration scientific phenomenon and/or principles.

LEARNING PROGRESSION: Purposeful sequencing of teaching and learning expectations across multiple developmental stages, ages, or grade levels. The term is most commonly used in reference to learning standards (in this case, Common Core Standards).

PHYSICAL LABORATORY: A laboratory exercise that is completed in a hands-on method in the classroom. It does not involve the use of computers; rather it involves the use of actual materials.

SCIENCE COORDINATOR: An individual who works with all levels, grades, and buildings within a single district to provide a comprehensive plan and appropriate support for meaningful science education.

SCIENTIFIC THINKING: The process of extending knowledge by forming a hypothesis based on observations and epidemiological patterns, which is then tested on a subset of the total population, then generalizing the results to the appropriate population through the process of inductive logic.
Chapter II

Overview

In order to complete an effective professional development, research has been collected about various aspects of elementary science education. First, research is presented regarding the declining role in elementary science. This information is presented so that one can understand the various and complex issues for the decline of elementary science in the United States. Better understanding of this information can allow for a solution to arise; in this case, a professional development that tackles some of the issues presented.

Next, we look at the research surrounding student needs in elementary science education. This is critical information as it will be used to create a professional development that can allow for teaching that is student-centered in nature. The student need highlighted in the research presented is inquiry-based instruction as research has suggested that it is the single-most effective method in the science classroom. This research is supplemented by information regarding the various levels of inquiry. This information proves useful is not only teacher education, but lesson planning and science instruction as well.

All of the information connects as these pieces serve as the fundamentals from which a remedy can be derived in the form of a professional development. As a result of the research, a professional development can be created that takes into consideration the history of the role of science education in the classroom, teacher needs and student needs. Once this information is better understood by teachers who have participated in the professional development, greater student learning can be achieved in elementary science classes.
The Decreasing Role of Elementary Science Education

The most important goal of contemporary science education is to produce scientifically literate adults (Zimmerman, 2007). Of course, not all students pursue careers in science, however, the thinking skills used to understand science can be related to other formal and informal thinking skills (Kuhn, 2002). Currently, recent efforts to reform and improve the way science is taught strives to make certain that those who do not pursue a career in science are able benefit from the basic thinking skills taught in the classroom (Ford & Forman, 2006; Metz, 2004; O'Neill & Polman, 2004). By focusing on interventions that encourage the development and practice of investigation and inference skills, science education will become increasingly relevant to the needs of all students (Zimmerman, 2007).

This information aligns with the current goal of the National Framework for K-12 science education, which is to ensure that by the end of 12th grade, all students have some appreciation of the beauty and wonder of science. This includes their ability to possess sufficient knowledge of science and engineering information to adequately engage in public discussions on related issues. These abilities will increase in time with a goal of creating a student body that is able to continue to learn about science outside school. Further, it strives to create students who are careful consumers of scientific and technology. Most importantly, the framework strives to ensure that American students have the required skills to enter careers of their choice, including (but not limited to) careers in science, engineering, and technology (U.S. Department of Education, 2008). These goals are meant to hold true in elementary schools as well as it is here that children receive their initial experience of formal science education. They are taught, by selection of national and state curriculum, what matters in the world and how to deepen their understanding of concepts presented. Despite the goals and intent of elementary science education, the role of science in elementary grades has been declining steadily in the United States according to some national and private research as presented below.
Potential reasons for the decline

The potential issues regarding the reasons for the decline are many. First, a great deal of research reflects that a general decrease in the amount of time spent of elementary science education is the cause for a general decline. The National Center for Education Statistics has created and published information regarding the actual amount of time spent on Math, ELA and Science between the years 1987-2008. Specifically, two figures were presented that summarize the fluctuations in time spent on ELA, Math and Science between these years for elementary school students in grades one through four. In focusing specifically on science, 26 years ago, approximately 2.6 hours per week was devoted to science education. This number peaked between 1994-1999 at 3 hours per week and had declined steadily from the year 2001 to 2.3 hours per week (or 7.1% of a student’s school week). It is important to note that NCLB was signed in 2001. Conversely, ELA and Math have increased since 2001, with ELA having the greatest percentage increase in hours per week.

Figure 1: Elementary Instructional Time (Hours per Week) by Subject

![Image of Figure 1](http://nces.ed.gov/surveys/sass/tables/sass0708_005_t1n.asp)

This information is further summarized into the percentage of time spent by subject per each work week from the years 1897-2008. The fluctuations between an increase in science is directly related to a decrease in time devoted to ELA. Overall, fluctuations have always ranged within two percent of the time spent on science over 20 years ago. This information serves to point out that there are only so many minutes per school day and that there is limited time for students to learn all of the information that our ever-changing society feels they should have an understanding of during their formal education. In point, this information is useful to point out the idea that time may not necessarily be a center issue at hand.
Reasons beyond the actual amount of time have been researched in depth as well, including the attitudes and perceptions of elementary teachers. When not regulated or accounted for, elementary teachers have a general choice to teach, or refrain from teaching science, prior to the NCLB act. Conderman (2008) worked to identify some of the reasons from the perspective of in-service elementary teachers. He found that some of the reasons for a lack of a desire to teach science include: (1) an individual perception lack of a general lack of science or technology skills; (2) an unfulfilled request for meaningful and effective professional development; (3) inappropriate funding for necessary science equipment or supplies; (4) to standardized testing resulting in increased demands to prioritize math and reading; and (5) classroom management issues such as time constraints or behavioral issues associated with science activities. These concerns are compounded by a recent increase of inclusive classrooms and the requirements that students with disabilities have access to the general education curriculum and highly qualified content-area teachers (Conderman, 2008).

The issue of funding may be the most difficult for some schools as it was found that teachers working in schools with lower socioeconomic status (i.e., those with higher proportions of students on free and reduced lunch) appeared to use more traditional teaching practices than did their counterparts from schools with more wealthy student populations (Supovitz, 2000). Additionally, significantly lower levels of both investigative culture and inquiry-based practices were found among students in schools with some degree of poverty. For each additional standard deviation of students receiving lunch assistance, all else being equivalent, teachers used inquiry-based practices approximately 20% less frequently and had nearly a 30% less frequent use of investigative culture (Supovitz, 2000). Essentially this means that students from schools with a lower income status, which are most often urban schools, do not receive the same science education as their suburban counterparts. The reasons may include the fact that teachers may feel students are not capable of inquiry level thinking, that student behavior may not support inquiry-based instruction, or perhaps. Additionally, less experienced teachers are more frequent in these schools as it is easier for a new teacher to obtain a job in such schools.
Next, the NCLB has taken a large portion of the blame recently in the potential reasons for the decline of elementary science education. The act specified that science standards were to be in place by the 2005-06 school year and implemented by the 2007-2008 school year. At this time states were to have science assessments in place that would to be administered at least once during grades 3-5; grades 6-9; and again in grades 10-12 (Gross et al, 2005). Currently, there are thirty-one states that administer science assessments to only the three grades minimally required. On the contrary, mathematics and reading assessments are administered to at least seven grades in all fifty states (Judson, 2011). Further analysis of data from elementary schools found that since NCLB mandates have been in place, time spent on science was cut by at least 75 minutes per week in at least half of the reporting districts (McMurrer, 2008). Based on this information alone, one can attribute the NCLB act towards negatively impacting science education in elementary schools across the nation.

To extend this, research and philosophy exists that would make one believe that a decrease in science is needed in order to increase basic literacy skills, which is among the most common of buzz words in the education industry currently. However, Judson (2011) states that choosing to use larger amounts of science in their elementary curriculum did not lose ground in other subjects. Further, fourth-grade data indicated that the states using science in their accountability programs had significantly higher science achievement than the other states in secondary education (Judson, 2011). This simply means that states who measured science achievement beyond minimal expectations, using a district-created method of assessment, nurtured greater amounts of science leaning. This translated into a student body with greater science literacy skills than those districts accepting only the bare minimum of science instruction. Clearly, implementing science education to students early on can result in increased science achievement in secondary science education.
Identifying Student Needs in Instruction: The Importance of Using Inquiry-Based Instruction

The National Research Council of America feels that the most effective method for reaching students is through the use inquiry teaching that proves to be engaging (Ireland, 2012). Inquiry is defined as a set of interrelated processes by which students pose questions about the natural world and investigate phenomena (National Research Council, 2000). When students learn science in this matter, students are better able to understand the concepts, principles, models and theories associated with scientific literacy. Inquiry-based learning should be a powerful component of all science programs across all grade level. Further, this notion should touch each domain of science from the elementary to secondary years. It is recommended by the NRC (2000) that the designers of curricula and programs ensure that the approach to content, as well as the teaching and assessment strategies, reflect the acquisition of scientific understanding through inquiry. The theory behind utilizing this method is so that students have the opportunity to learn science in a way that reflects how science actually works in the real world. Next, students benefit from teaching methods that encourage scientific thinking throughout an entire lesson.

Scientific thinking is defined as the application of the methods or principles of scientific inquiry to reasoning or problem-solving situations, and involves the skills implicated in generating, testing and revising theories, and in the case of fully developed skills, to reflect on the process of knowledge acquisition and change (Koslowski, 1996; Kuhn & Franklin, 2006; Wilkening & Sodian, 2005). During this process, it is hoped that students engage in some or all of the components of scientific inquiry. This includes items such as designing experiments, evaluating evidence and making correct inferences to name a few (Zimmerman, 2007). The goal here is for students to actually determine the appropriate actions to take to solve a scientific issue at hand. Once accomplished, they have a greater possibility to correctly test this method. Once completed, a proper analysis of the hypothesis should take place with thoughtful reflection from the student. Ideally, the student should be able to understand his/her own mistakes, and recalculate the experiment to overcome them. Utilizing such methods has been proven to be extremely successful, especially when taught through utilization of the inquiry method.

Supporters of inquiry based instruction cannot argue that doing science far exceeds talking about, or even writing about science. To enhance this, the benefits learning environments outside the classroom should be
considered and used as often as possible (DeWitt & Osborne, 2007). Such places can include nature centers local to the school, various science and educational museums, local zoos or other locations that can extend subject matter by allowing students to interact with concepts studied in their natural state. The campus of a school itself may prove to be an excellent tool and alternative classroom setting, especially if teachers and administrators can work to create a space specifically dedicated to science curricula.

There are several ways to determine if a class activity or experiment is one that embraces inquiry learning. First, and most basic, is that students are using data analysis to answer a research based question (NSTA). This is important as the ability to understand the results garnered from an experiment is a critical step of the inquiry learning process. The inquiry–level is achieved when students then use that information to answer the questions they deemed appropriate at the beginning of the lab or experiment. Next, questioning is critical to the inquiry process. Cecil (2011) states that intentional questions derived by students can foster connections between different aspects of content. This connection can then lead to deeper connections across the content of study. Essentially, higher-level questioning can result in several high level responses. Last, allowing for reflection that allows students to move within a range of positions within the experiment itself (from questioning, to creating predictions, experimenting, analyzing data, revisiting steps based on knowledge gained within the experiment, etc) is critical to ensure that students were able to make unique connections to the data that are meaningful.
Need for Professional Development and Teacher Education

Internationally, schools are under increasing scrutiny for the amount of inquiry based lessons they utilize for all grade levels (Lunetta, Hofstein, & Clough, 2007). “Inquiry-based laboratory investigations at all levels of science education should be at the core of the science programs of schools across the nation; inquiry should be woven into every lesson (National Science Teachers Association (NSTA, 2007). Simply stated, this means that teachers should be required to have a firm understanding of what scientific inquiry learning is as well as what pedagogical practices are required to help achieve it in students (Ireland, 2012). Though much has been written in support of practices that foster inquiry learning, many researchers feel it is yet to be applied extensively in the average teacher’s daily practice (Asay & Orgill, 2010; Goodrum, Hackling, & Rennie, 2001). It is only with the understanding of inquiry-based instruction alongside a firm understanding of the NOS that these principals can be properly utilized in a science classroom.

It is important to look at quality of science instruction of our nation’s pre-service teachers. A focus of research, including work completed by Abd-El-Khalick (1998) clearly identifies several examples of teachers, both pre-service and in the classroom, who simply do not understand the most basic scientific concepts. Teachers who lack such skills simply cannot offer a robust elementary science education. Of the most important concept to understand is the Nature of Science (NOS) as it is at the root of all science leaning. As stated by McComas (2002), the nature of science is a fruitful arena which blends aspects of various social studies of science including the history, sociology, and philosophy of science combined with research from the cognitive sciences such as psychology into a rich description of what science is, how it works, how scientists operate as a social group and how society itself both directs and reacts to scientific endeavors. In order to accomplish such a thorough understanding of this belief into students, the teacher themselves must also understand and appreciate scientific contributions, processes and the rich history of science and how this information is useful to current science standards. To describe the various methods in which NOS education can occur, McComas et al. (2002) defined and analyzed the possible advantages and disadvantages for NOS education under a variety of circumstances as follows.
1. **Nature of Science in Methods Courses:** In this strategy, the content and pedagogical strategies of the nature of science are communicated within a science teaching methods course.

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<th>Advantages</th>
<th>Disadvantages</th>
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<td>* NOS content is discussed in an environment where curriculum and pedagogical connections can be immediately discussed. * Students may be more receptive to the unfamiliar topics within the nature of science by encountering them with familiar faculty discussing familiar and applicable topics. * May facilitate discussions of the parallels between the development of science itself and the learning of science.</td>
<td>* Blending the nature of science with methods include the possibility that other topics may be neglected. * NOS itself may get less than adequate treatment given the many other issues needing attention in methods courses. * Suggested NOS teaching methods may illustrate how to apply some NOS concepts, but miss other fundamental ideas and their integration with science content.</td>
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2. **Nature of Science in Science Content Classes:** This approach requires that significant attention to relevant nature of science issues be intertwined with the teaching of science content.

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<th>Advantages</th>
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<td><strong>Advantages to NOS in Science Content Classes</strong> * Students can see the application of the nature of science in context, thus legitimizing the nature of science as a useful domain. * Students in the class who are interested in the education have explicit modeling to draw from when designing instruction.</td>
<td><strong>Disadvantages to NOS in Science Content Classes</strong> * Science faculty members may not know how to discuss NOS issues. * In the college environment, methods students may not receive useful strategies enabling them to share nature of science content with their own students.</td>
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3. **Teachers as Scientists:** In this strategy, teachers of the nature of science should have had some authentic experience actually doing science so that they can talk with some authority about how science is done.

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<th>Advantages</th>
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<tr>
<td><strong>Advantages to the Teachers as Scientists Approach</strong> * If individuals learn about the nature of science by doing scientific research, those participating could speak with authority and enthusiasm about the NOS from first-hand experience. * Those who have had such experiences would be more able to guide students in pursuing their own research and science fair projects.</td>
<td><strong>Disadvantages to the Teachers as Scientists Approach</strong> * The assumption that those who do science learn enough about the nature of science to communicate it accurately. * The necessary strategies to translate NOS content into classroom practice are missing.</td>
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4. **Formal Courses or Units of Study in the Nature of Science:** This plan would have science teachers learn about the nature of science in a discrete unit of study or in a course taught by a science educator.

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<th>Advantages</th>
<th>Disadvantages</th>
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<tr>
<td><strong>Advantages to Formal NOS Courses</strong> * A specific nature of science course or unit of study would guarantee that students see the fruitful connections between history, philosophy, sociology and psychology of science. * Experiences in the course would likely be tailored to the needs of practicing science teachers. * Discrete courses could be implemented without revising other aspects of the education curriculum.</td>
<td><strong>Disadvantages to Formal NOS Courses</strong> * Specific courses invariably require additional time that may impact other useful courses. * A discrete NOS course may be disconnected from science content possibly diluting its relevance. * If the course involves science teachers then it is vital that such courses connect to problems of teaching NOS.</td>
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There are additional criteria that are believed to make professional development of greater value to both pre and in-service teachers. Exceptional professional development must allow participants to experience inquiry. This can be done through activities designed for teachers that utilize inquiry-based questioning and experimentation. The goals of such are to directly model inquiry forms of teaching so that the teachers themselves have a personal experience with the process of inquiry instructions (Arons, 1989; McDermott, 1990; Bybee, 1993). Further, Marek and Methaven (1991) found that teacher education programs (also including both pre and in-service teachers) that model scientific reasoning have a greater positive influence on student achievement than did other programs. This is especially true of programs aimed at teaching both elementary and secondary teachers to use specific curricula. These thoughts are compounded by findings that a teacher’s specific understanding of inquiry based instruction does indeed have an influence on individual teacher practice (Ireland, 2011). Simply stated, when teachers are taught to teach students with inquiry-based practices and an understanding of the nature of science, greater student learning is accomplished.

Loucks-Horsley et al. (1996), furthers the above understanding of professional development; they found that it is a critical aspect to improving not only science, but mathematics as well. Essentially, any type of processed-based learning involving the ability to problem solve can be positively affected by professional development highlighting inquiry. Specifically, it was found that the most beneficial experiences for science and mathematics educators include the following seven principles to be imbedded within a professional development schema. First, all teachers should understand the basic notion that all children can and should learn science. Teachers should learn methods to teach children how to approach scientific knowledge and utilize needed skills to help them construct new understandings. This works best when the new understandings are associated with items they already have an understanding of. Again, an emphasis on inquiry-based learning, problem-solving, student investigation and discovery, and application of knowledge should be a focus. This is important as much of pre-service science education simply includes a variety of topics they may or may not teach. The information barely scratches the surface so to speak of an actual understanding of the issues and...
information at hand. This may not be communicated to teachers in an appropriate manner. Collaborative work should be included often to promote discussion as well as the opportunity for students to explain concepts from their own point of view, thus making personal and meaningful connections. Teachers must always provide clear outcomes and expectations alongside thoughtful assessment at various points during the learning process. All of these ideas must also take into account the diverse learning needs of individual students from different cultures, races, and gender (Loucks-Horsley et al., 1996).

To further these ideas, it has been found that a strong relationship exists between high quality professional development and the kinds of teaching practices that are advocated by science reformers lead to teachers better apt to utilize inquiry in their classroom (Supovitz, 2000). Additionally, the greater the amount of professional development, the higher the instances of Investigative Practices and Investigative Culture were noted in classrooms, as seen in Figure 2 below. This simply indicates that more genuine inquiry-based teachers occurs when a teacher commits to (or is provided the opportunity to commit to) extensive professional development.

![Figure 2](image)

*Figure 2.* The relationship between different levels of professional development and classroom practice and culture (Supovitz, 2000)

When professional development classes use instructional methods to promote learning for adults which mirror the methods to be used with students, students benefit (Loucks-Horsley et al., 1996). In point, Loucks-Horsley et al. (1996) urge schools to creating time for professional development because teachers require regular, scheduled blocks of time for working and learning together. Administrators can support such
development with some considerations made regarding scheduling, staff assignments, and general time allocations.

In sum, despite issues regarding a lack of elementary science teacher preparedness, skills or understanding of the Nature of Science, a solution can include professional development for both pre and in-service teachers. Schweingruber (2007) conducted research which proves critical; a teacher’s belief systems can change tremendously in a short period of time. This change best occurs when the new information being conveyed is easily understand and thought to be accomplishable by the teachers Hollon, Roth and Anderson, (1991) add that “Science teachers must develop knowledge that enables them to make two types of decisions—curricular decisions and instructional decisions (p. 149).” From this, a challenge is created for science teachers before so much as stepping into the classroom. They must possess the ability to translate an understanding of the knowledge generation process into significant classroom experiences combined with appropriate classroom dialogue (McComas, 2002). Further, Abd-El-Khalick conducted research that demonstrated that pre-service teachers could benefit from student teaching placements with teachers who effectively taught with NOS ideas in mind; NOS and Inquiry instruction should be an aspect of all pre and in-service education.
Issues regarding Inquiry and Implementation of Professional Development

From the Perspective of Students and Education

First, despite the national push for inquiry, a single model of scientific inquiry, from which these theoretical models are often based, does not exist (Osborne & Collins, 2003). In 2003 Osborne and Collins performed a Delphi study of 23 science education community experts with the intention of learn the most important attributes of science and inquiry from the perspective of experts within the field. The central purpose of the study was to identify common themes that were considered important to a proper science education with the goal of creating a professional development to help alleviate current issues in elementary science education. The study found nine themes which all experts reported a high degree of importance. They include: (1) a proper understanding of the scientific method; (2) the meaning of certainty as defined in science with the consideration of scientific proof; (3) the history of scientific knowledge, findings and processes of identifying theories; (4) appropriate questioning; (5) a variety of scientific thinking skills; (6) analysis and elucidation of data; (7) hypothesis and prediction; (8) appropriate collaboration in the development of scientific knowledge, and (9) creativity with the goal of making science education both engaging and inspiring (Ireland, 2012).

The issues regarding the use of inquiry are equally important to note. Newman (2004) wrote about pre-service teachers and student frustration when utilizing inquiry-based instruction and shed light on some issues which may be often overlooked. First, it was found that students can easily become frustrated when answers are not clearly presented. While the point of inquiry-based instruction is to get students to build answers on their own, an answer should always reached by the end of the lesson or unit as planned by the teacher. To ease frustration, students should not be left with open-ended questions that result in from ineffective teaching or poorly designed lesson plans. Second, students felt that inquiry-based lessons can be feeble or lacking science concepts when compared to more traditional science lessons. Next, from the teachers’ perspective, they stated that they disliked inquiry because they were not taught using this method in their science education. They elaborated that this method of teaching often feels awkward. This is surprising, however, because as life-learners we use inquiry on a daily basis even if we may not label it as ‘inquiry-based problem solving.’ Last,
both students and teachers felt that inquiry-based lessons were somewhat time consuming especially in comparison of traditional methods of delivering a lesson (Newman, 2004). In my opinion, these items can all be overcome with proper planning by the teacher combined with confidence gained by a firm understanding of how to properly use inquiry.

**Conclusion**

Overall, it has been found that there is indeed a general decline in amount of time spent on elementary science education. A teacher’s perception of the importance of science and attitude towards teaching science rests greatly with the perceptions of those closest to them, including colleagues, administrators, and district attitudes. Essentially, science education rests with those in the ‘management’ positions of elementary schools. Of course, those attitudes and opinions come largely from state and federal initiatives.

Further, it has overwhelmingly been found that to improve the quality of education, inquiry-based methods must be utilized alongside a proper understanding of the nature of science by elementary teachers. Increased pre-service science education will be beneficial towards the goal of producing science literate students. Regular opportunities for effective professional development for in-service teachers is also critical. It has been found that teacher education practices that use inquiry-based methods will provide them with first-hand exposure to the inquiry process, thus making their experience more authentic. Doing so will allow them to teach using correct inquiry methods.

The most logical solution to these issues would be for a single, well-proven plan (with a central goal in mind) to come into play for our education system that focuses on the skills needed to compete in a global market and allow student to excel in science literacy. Ensuring that our teachers are utilizing inquiry-based practices while educating teachers on the Nature of Science and inquiry instruction will be at the basis of this plan. Proper professional development and materials are required to make this goal a reality. This goal will serve all students well as the critical thinking skills needed in science are applicable to all areas of life. Further,
achieving greater science literacy will allow our students to compete globally in a market that is moving rapidly
toward science and technologically based careers.
Chapter III

Overview

Chapter III will identify the specific course of action created to enhance elementary science education and is based on the researched presented in chapter II. The project design is detailed, followed by the handout that will be used during the professional development. It concludes with a sample weather unit that can serve as a basis for teachers to model their unique plans after.

Next, a Power Point file accompanies the teacher handout. The power point includes three different presentations that would be used at three different times. The presentations are progressive in nature, hence, will be more effective if teachers are allowed time to practice with the information gained before undergoing the next professional development. Each power point contains specific information about *Elementary Science Education, Teaching with Nature of Science and Inquiry in Mind*.

The first section is subtitled: *Part I: Understanding the Nature of Science*. Here, teachers will gain insight to the basic nature of science on a level that is useful to elementary classrooms. First, teachers begin with the Marshmallow Challenge that serves as an ice-breaker as well as an opportunity for teachers to practice some of the skills they will learn about within the presentation. The current goals of science are the highlighted after teachers have an opportunity to watch a short video that presents science as a life-encompassing manner that is both inspirational and thought provoking. Next, teachers are presented with the ideas that science nature is both stable yet malleable, while also being tentative to the current findings within the science community. We then review specific definitions in science while highlighting that these words differ from their ELA-based counterparts. The scientific method(s) theory is then discussed as one that does not necessarily represent science in its natural state as both doing and learning science are not linear processes by nature. We discuss that mistakes are valuable information, relating back to items learned while making what seemed to be mistakes from the Marshmallow Challenge. We close with a larger discussion on observation and inferences and complete an activity that can also be used by teachers within their own classrooms to differentiate these two useful terms.
The second section is subtitled: Part II: Understanding Inquiry-based Instruction. Here teachers begin by reflecting upon their own definition of inquiry as research shows us that personal perception of this term affects how we utilize it. We then complete a fairly lengthy laboratory that allows teachers to practice and recognize inquiry skills, while learning an important aspect of creating their own labs. Teachers will see that following the basic directions did not lead for the answers they were looking; they be forced to re-evaluate their current work and results and identify new questions based on their experiences. They will complete a lab that is not linear in fashion, rather one that requires teachers to seemingly start-over while devising their own unique method to solve the issue at hand. Inquiry is then formally defined, followed by sharing of the personal definitions created by the participants within the group. We strive to create one definition of inquiry that encompasses all that we have learned about it. It will be reiterated from the original slideshow that science learning is not a linear process. We then discuss the idea that students should be the ones largely responsible for both the questions and methods utilized to solve those questions when doing an experiment. We close with an activity that highlights inquiry as a method to teach an understanding of a definition before students are even of the word they are defining; in this particular activity, density is the term at hand.

The last section is subtitled: Part III: Developing Higher Level Inquiry Questions. For this section, we begin with a discussion on questions that highlights the fact that most teachers already use a diverse array of questioning strategies for classroom activities. Learning to incorporate the higher-level strategies into their science activities is not a daunting task, rather, one that focus on more time to the actual question itself. A brief video presents information that depicts an extension of the top tier of Bloom’s taxonomy in the process of developing high level inquiry-based questioning. We then differentiate between vague and specific questions, followed by an activity where we use questioning as a method to make decisions. The focus, however, is on the questions themselves, rather than the specific decisions we are looking to make. We view a sample of method to discuss and evaluate questions for students and then practice that method by completing a task in groups. We then close with an experiment where teachers can understand the importance of stopping during a lab to allow
for questioning, as opposed to only creating questions at the beginning of the lab. We learn that questioning should occur at various stages of all science and inquiry-based activities.

A comprehensive lesson plan that encompasses the ideas taught in the power point is also included and serves as an example for teachers to use when creating their own unique inquiry-based lesson. It is not intended to be used to replace their original thoughts, ideas and lessons that they feel are appropriate for the learners in their classrooms. Rather, it serves as a means to further view lessons and ideas that may be effective for their classes in light of common core science goals.
Project Outline

This project will include a full six-year unit of study (Grades K-5) of one Earth Science topic that will serve as a foundation for successful science curriculum implementation in elementary education. It would be recommended that 8-10 total units be developed that cross all disciplines of science to better prepare students for their secondary science education. Aspects of Literacy, Technology and Mathematics will also coincide to make the science education robust and applicable to multiple levels of student learning. The specific grades covered will be a result of the curriculum outlined by the Common Core and NGSS learning standards. The entire unit will include an appropriate progression of learning.

The project includes the following:

1. **Power Point presentation entitled Elementary Science Education: Teaching with the Nature of Science and Inquiry in mind. (Including “Instructor Points” that will be highlighted throughout the presentation.**
   a. Part I: Understanding the Nature of Science
   b. Part II: Understanding Inquiry
   c. Part III: Developing High-Level inquiry Questions

2. **Teacher handout:** used for notes and reflection. Includes “Instructor Points” that will be highlighted during the presentation.

3. **Sample lesson Plan:** minor point of project that serves as an example for teachers to utilize when considering the creation of their own inquiry based lessons.

Each lesson within the sample unit will include:

1. Title of lesson including what unit the lessons belongs to
2. NYS/NGSS standards that fit the lesson and/or lab
3. The extension of the lab to secondary Earth science education (NYS Earth Scicne Standard).
4. Integration among other disciplines (for example, science and technology, science and literacy, etc)
5. A list of materials required for the lesson
Overview of Elementary Education Weather Unit, grades K-5.

The six year Earth Science Module will include an introductory lesson in kindergarten and will follow up with Units in 2nd and 5th grades as outlined by NGSS. A unit is present in Kindergarten simply to make an introduction to the unit and create background knowledge to enhance the overall learning progression.

**Grade Kindergarten:** Teacher will read a book about the seasons and, with the class, brainstorm a list of weather terms that they have experienced (temperatures and precipitation forms). Students will take 4 “field trips” outside to the school playground to collect samples from the current season to graph. Students will learn about climate vs. weather. (Science, Data Collection and Literacy)

**Grade 2:** Students will complete three miniature laboratory experiments on air pressure and understand how air pressure affects wind. Students will learn that wind affects weather patterns. Students will be introduced to the term isobars. Students will understand that isobars represent boundaries between areas of high and low pressure. Students will learn that these differences create wind. (Science, data collection, graphing)

**Grade 5:** Students will construct individual weather stations (based on Earth Science Reference Tables models) to create a weather report for a city of their choice (fictional or non-fictional). Students will then become meteorologists and forecast the weather based on their weather station while being recorded by their peers. After each weather report has been viewed, students must connect their cities by isotherms. Students will collaborate to identify areas of high and low pressure and place red (high) or blue (low) yarn over the cities to represent this. (Science, Technology, complex Problem Solving and decision making)
Elementary School Education:

Teaching with the Nature of Science and Inquiry in mind

Part I: Understanding the Nature of Science

(See Accompanying Power Point Presentation)

Teacher Guide

By Amy Visca 2014
Agenda/PD Overview

Opening: (15 minutes)

The Inquiry Marshmallow Challenge
(see attached page for supplies and instructions)

Teachers will learn that they can observe a great deal about their students by completing this in their class as an introduction to science inquiry. The skills used to build their tower are an example of the Nature of Science—the process of trial and error is the Nature of Science at its best!

Nature of Science: (10 minutes)

The Nature of Science Video and discussion

Discussion Points: Science includes and consumes every aspect (living and non-living) that we encounter in our daily lives. Science can be thought of from many different viewpoints based on the specific interaction; science can be beautiful, intimidating, thought-provoking, a form of truth, a form of questioning, a struggle and more.

Nature of Science Terminology (10 minutes)

Discussion Points: the nature of science includes observations and inferences. Terminology in science can differ from their expressed definitions from ELA based definitions. Learning from mistakes in science can often be more beneficial than getting something right the first time. Create opportunities where students need to take multiple avenues to reach a scientific finding.

Observations and Inferences: (20 minutes)

Discussion Points: Demonstration of observation and inference will occur and be discussed. Terms are defined and discussed. We will also see how to help students visualize these terms through the use of the book Seven Blind Mice, written by Ed Young.
Opening: The Marshmallow Challenge!

Use the supplies on your table to create a structure.
The Marshmallow MUST be at the top.
Points awarded for creativity and height of structure.
You have 10 minutes, good luck!

Activity Reflection:

You and your team used:
Collaboration
Inquiry Skills
Process Trial and Error
Communication and Collaboration of Ideas
Trouble Shooting

In a word ……you and your team used SCIENCE

What could you learn by using this in your classroom?

Instructor: When used in the classroom, this activity can help us gather a great deal of information about our students. We can learn information on how to group students (i.e. who are the “leaders” and who needs to be encouraged, etc.). In doing this experiment (which can be modified by adding large marshmallows for bases or thicker pasta for younger students) students can enjoy trial and error. They can understand an aspect of the Nature of Science. The can see firsthand how making mistakes can lead to learning, and actually try again based on the knowledge of their mistakes. It is important to teach students that great information can always be learned whether or not the experiment is going as planned. The process should be interactive. For example, maybe you learned that 3 pieces of spaghetti cannot support a marshmallow so next time, you use four!
What is Science video

While watching the video, write down your thoughts, responses or questions about what you are seeing.

__________________________________________  ______________________________________

__________________________________________  ______________________________________

__________________________________________  ______________________________________

Did anything in the video surprise you?

__________________________________________

One of the words used to describe science was “struggle.” What do you think the author meant?

__________________________________________

How can we make learning science less of a struggle for our students?

__________________________________________  ______________________________________

__________________________________________  ______________________________________

Inquiry  Nature of Science

Fun Fact: The violin music playing during the video stimulated your brain, making your emotional responses heightened and therefore, the video more effective. Try playing light instrumental background music in your class while doing labs for the same responses!
Nature of Science

We can better understand the nature of science with the following information:

1. **Scientific knowledge is tentative.**

Although scientific knowledge is supported by a wealth of data from repeated trials, it is not considered the final word.
   - A. Scientific knowledge is at the same time stable and malleable.
   - B. Scientists continually test and challenge previous assumptions and findings.
   - C. Science is a human endeavor, and we know human perspective is limited and fallible.

This idea of fundamental uncertainty is vital to scientific studies and is the basis of great scientific discoveries.

For example:

   Let’s say we found the cure for a rare form of cancer today. Is it the best cure? Will it work for everyone?

   The answer may be “yes.” If so, that’s great right?!
   - 3 months later a new plant species is found in the rainforest that can enhance the cure... So science evolves the cure.
   - 2 years later it is found that individuals who have used this treatment are experiencing an array of negative side effects...So science further evolves the cure.

**Instructor:** The items that are considered factual in science (i.e we have found a cure) can and will change as new factors are put into the original equation. This cycle has been occurring and will continue to occur as long as humans (or other intelligent species!) can exist.

2. **Scientific Definitions: Definitions in science differ from ELA-based definitions.**

   - **Fact:** A “Fact” in science must be one that can physically be observed using the 5 senses in a current setting.
   - **Hypothesis:** An educated guess that takes into account something from experience alongside an observed fact.
   - **Theory:** A Theory in science is also known as a “Scientific Truth.” It is the best assumption we can make with the given information. Of course, all truths can be adjusted with new information...
3. The Scientific Method: There is not a single method which scientists use, nor is science intended to be a linear process.

In this process, the question is the most important aspect!

4. Mistakes do not equal failure. It is critical to teach students that mistakes are both expected and valuable. Unexpected results are important to understand by students because mistakes contain valuable information as well.

What are some ways we learn from mistakes in science?

- 
- 
- 
- 

5. It is important to distinguish between the terms Observation and Inference.

**Inference**: The act or process of reaching a conclusion about something from known facts or evidence

**Observation**: The activity of paying close attention to someone or something in order to obtain information; may require use of tools.

Let’s record a few Observations:
**Instructor:** Don’t turn the page until directed- we don’t want to ruin the surprise!

What inferences did you make throughout the demonstration?

After lighting the top:

As instructor took a bite:

How did your *inferences* change as you were able to make more *observations*?

Observations and inferences can be well illustrated to elementary students using the book *Seven Blind Mice* written by Ed Young.

*(Instructor will read book to participants)*

![Seven Blind Mice](image)

Concluding Thoughts:

THANK YOU!

Part II Professional Development End.
Elementary Science Education:

Teaching with the Nature of Science and Inquiry in mind

Part II: Understanding Inquiry-based Instruction

By Amy Visca
2014
Opening: (20 minutes)

The “Dirty Pennies” Lab

Discussion Points: Teachers will write their definitions(s) of inquiry on 2x5 cards. We will complete the Dirty Pennies Lab using inquiry. We will discuss that the process of trial and error is inquiry teaching at its best! We will speak briefly about the importance of graphing to help students interpret and record their results.

Inquiry Defined: (10 minutes)

Discussion points: We will review some accepted definitions of inquiry and review all of the various definitions that teachers came up with individually on 3x5 cards. We will discuss the multifaceted definition of Inquiry and what it means as teachers and students and well as some research surrounding inquiry.

Forms of Inquiry (10 minutes)

Discussion Points: Inquiry is not a linear process (in contrast to the “Scientific Process” which can make scientific learning appear to be linear in nature). Inquiry laboratories and teaching should take in new information, then go back in the cycle, multiple times if necessary, until conclusions can be drawn that make sense. Levels of Inquiry should be considered by teachers to ensure a robust science experience for students. Students should be creating own questions and determining best method for solving those questions.

Sample inquiry activity: (20 minutes)

Discussion Points: Inquiry occurred (that was guided at different levels by the instructor based on each groups individual progression) as students used materials to understand the concepts of density before understanding any text-based or scripted definitions of density.
Instructor: Inquiry can be defined in many different ways that can be different for professionals, students, and teachers. The way we define inquiry had an effect on how we use inquiry in our classrooms. Therefore, it is very important to have a concrete definition of what inquiry is to you and what this means. Please write as many definitions as you can about what you feel inquiry is. Include what it means, what it may encompass and what is can be used for.

What was one response you wrote on your 3x5 card?

Dirty Pennies Lab.

When thinking about using inquiry, these are some questions that should be considered after an experiment is completed OR during the process if the experiment is not finding the answers sought.

- Did your method change along the way?
- Did you alter your experiment based on your first trial?
- Did you reconsider your question based on the results during and after the experiment?
- Do you feel your experiment was conducted in the best way possible? What would you have changed? What would you do the same?
- How did you know you reached the desired result of the experiment?

How do we use this information – What does the research say?

There have been countless studies on best practice in science classrooms. Here are the highlights:

1. The National Research Council of America feels that the most effective method for reaching students is through the use inquiry teaching that proves to be engaging (Ireland, 2012).

   **in·qui·ry**
   noun \in-ˈkwī(r-)ē, ˈin-ˌ, ˈin-kwē-rē\ :
   a request for information
   : an official effort to collect and examine information about something
   : the act of asking questions in order to gather or collect information

2. Teachers must possess the ability to translate an understanding of the knowledge generation process into significant classroom experiences combined with appropriate classroom dialogue (McComas, 2002).

3. A teacher’s specific understanding of inquiry based instruction does indeed have an influence on individual teacher practice (Ireland, 2011).

Different levels of inquiry can be used at various stages of any experiment and should reflect a group (or individual students’) specific needs.

Instructor: Essentially, inquiry means many things which encompass science. From an instructional point of view, it means that students are not handed the information; rather, they should develop their own questions and methods for answering.
What were some definitions of inquiry presented by your colleges that you found meaningful?

Inquiry is not a linear process (in contrast to the “Scientific Process” which can make scientific learning appear to be linear in nature). Inquiry laboratories and teaching should take in new information, then go back in the cycle, multiple times if necessary, until conclusions can be drawn that make sense.

Instructor: When devising inquiry-based lessons and working through the process, begin by asking students to select any area on the “wheel” and envision what that area may look like. How may the other areas influence that one box? Having students draw a concept map can help visualize the interconnectedness of each step of the inquiry process.
Instructor: For example, you may want to start with controlled inquiry in a first grade class to get students moving in the same direction. Then as students break into groups, some may have an aid and complete guided inquiry whereas more independent students work in the modeled inquiry category, based on their past experience. For those students with the highest abilities, free inquiry can take place. Essentially, inquiry can be scaffold and diversified as needed to suit specific student needs. Each individual lesson will fluctuate within the pyramid as this too is not a linear process.

Let’s think about the Spaghetti Challenge you completed from the first Professional Development in this series. With your group, think of a few ways you could use different levels of inquiry in your specific grade to complete the same challenge.

Instructor: There are countless ways to take a single assignment or laboratory experiment and incorporate different levels of inquiry that are appropriate for all grades. For the next activity presented, let’s think about different questions we could ask as we are finding different methods to answer our predictions.

Activity Predictions: What will float?

Orange_____

Banana_____

Avocado _______
(complete lab)
Write as Many Questions as you can while completing the lab:

__________________________________________________________________________

__________________________________________________________________________

__________________________________________________________________________

After completing the fruit lab, what was your experience with density?

__________________________________________________________________________

How does that experience compare to a definition of density presented on a handout?

__________________________________________________________________________

**Instructor**: Students should be coming up with their own unique:

1. The questions(s) for the lab or activity.
2. The information or experiences they may already have pertaining to the lab/activity
3. The best method to answer this question

**With practice, students will also gain/utilize:**

4. The ability to know when to move forward in their investigation, and when to revisit a step.
5. The ability to determine when they have enough information to answer this question.

THANK YOU!

Part II Professional Development End.
Elementary Science Education:

Teaching with the Nature of Science and Inquiry in mind

Part III: Developing High-Level Inquiry Questions

By Amy Visca
2014
Part III Agenda

Opening: (10 minutes)

What we know - Questioning

Discussion Points: Teachers will understand that they already have vast knowledge and experience with various levels of questioning. A short video will highlight Bloom's taxonomy and identify the top three levels as those that induce higher-level questions that are useful in inquiry classrooms.

Types of Questions: (10 minutes)

Discussion Points: Science includes and consumes every aspect (living and non-living) that we encounter in our daily lives. Our questions should consume every aspect of this thought. We look at vague vs specific questions to understand the idea that higher-level questioning can result in several high level responses.

Questioning Activity (20 minutes)

Discussion Points: Teachers will work together to determine what questions they should ask to solve an issue at hand. We will then determine how effective each question was and provide support for this reasoning. We will understand that taking time to discuss how to make effective questions should be a regular part of each and every experiment or science activity completed in class.

Closing Activity and Discussion: (20 minutes)

Discussion Points: We will complete a second activity that focuses on the importance of stopping during a lab, before a student understands what it is that they are devising. Teachers will look at an object they have created (based on specific instructions) and be asked to develop several questions and predictions based on their knowledge of that object. We will then work with a partner to think of examples within our current science work where we can create greater opportunities for questioning.
Welcome!

As teachers, we already know a lot about asking questions! We have all learned about Blooms Taxonomy and Costa’s questioning strategies.

Creating high-level inquiry-based questioning is just an extension of that… You are already well on your way to being a teacher who can easily devise (and help your students devise) high level inquiry questions!

Video:

What impressions do you have after watching the video?

______________________________________________________________

______________________________________________________________

Is incorporating higher-level questioning strategies very different from the types of questioning utilized in activities such as reading comprehension?

______________________________________________________________

______________________________________________________________

What are some of the methods we can use to develop high-level inquiry based questions for science lessons?

1. **The questions should be specific in nature.** For example:

<table>
<thead>
<tr>
<th>Specific Question</th>
<th>Vague Question</th>
</tr>
</thead>
<tbody>
<tr>
<td>What evidence do you have to support your ideas about that?</td>
<td>How do you know that?</td>
</tr>
<tr>
<td>What does that music remind you of in your own life?</td>
<td>Do you like that music?</td>
</tr>
<tr>
<td>How would you apply that concept to your own budgeting?</td>
<td>What did you learn about budgeting?</td>
</tr>
<tr>
<td>Could you explain how these two elephants differ?</td>
<td>What do you think about these two elephants?</td>
</tr>
</tbody>
</table>
2. Take the time to evaluate the effectiveness of the questions developed.

For example:

![Information Sheet](image)

**Activity 1:** Let’s devise some of our own questions for this scenario:

Imagine you are headed off to a deserted island in the Caribbean. ...And you only can bring one suitcase full of anything you can find in your house to survive. What Questions would you ask yourself to help determine which items are the most important to bring.

1. What are the most important things I am bringing, in order of importance?
2. What are some other ways I can use the tea kettle?
3. What are some tools I could use to change the tea kettle?
4. How can I make the food last the longest?
5. What will plastic do that canvas can’t?
6. What is the best use for each of the items?
Activity 2: Let’s create something new!

1. In the bottle on your work station, pour equal parts of tap water and rubbing alcohol until about 1/8 to 1/4 of the bottle is full.
2. Add 4-5 drops of food coloring and gently mix.
3. Put the straw in the bottle, but don’t let the straw touch the bottom (DO NOT DRINK THE MIXTURE).
4. Use the modeling clay to seal the neck of the bottle, so the straw stays in place.

Stop. Write two questions and predictions about what you can possibly do with what you just created.

1. ____________________________
   ____________________________

2. ____________________________
   ____________________________

(continue)

5. Wrap your hands around the bottle and watch what happens to the mixture in the bottle.

Observations: ____________________________
   ____________________________

Can you do anything else with your creation based on the questions you devised?
Give it a try and see if you can answer your own questions!

What did you make in your experiment? ____________________________

Closing: Think of three science activities you currently perform in your classroom.

With your neighbor, devise two high-level inquiry based questions that could be asked for each activity so that each of you has a total of six questions.

______________________________________________________________________________________

______________________________________________________________________________________

______________________________________________________________________________________

______________________________________________________________________________________

______________________________________________________________________________________

______________________________________________________________________________________

[43]
SAMPLE: Elementary Education Weather Unit, grades K-5.

The six year Earth Science Module will include an introductory lesson in kindergarten and will follow up with units in 2nd and 5th grades as outlined by NGSS. A unit is present in Kindergarten simply to make an introduction to the unit and create background knowledge.

The idea is that this unit is one of many that should occur across Kindergarten-Fifth grade. It is one piece of an intricate puzzle that, when created effectively, will address several concepts provide cross cutting throughout units. For example, in the second grade unit, students are required to understand simple planetary ideas. These ideas should be taught in a similar inquiry-based unit before this lesson is taught in second grade. If the units are devised in a manner that creates a proper learning progression, greater student achievement will occur.

**Kindergarten: Season sort (materials from all).** Draw a picture of each of the seasons. Discuss and read “Four Seasons Make a Year” (Science and Literacy)

**Grade 2 (a):** Experience weather in each season with 4 outdoor “field trips.” collect items from each season and complete lab sheet. Read a season book after each field trip. (Science, literacy)

**Grade 2 (b):** Air Pressure Lab; What does Weather do? (Egg in a bottle lab, weight of balloon, Salt Jar Wind)

**Grade 5 (a):** Building a weather Balloon (Science and engineering)

**Grade 5 (b):** Weather Stations and Maps Lab; Meet a local meteorologist.

**Grade 5 (c):** Create weather forecast, record and share (Science and technology).
Science Concepts Explored: Observation, Senses, ability to communicate scientific findings, sorting and graphing data. Science and Engineering, Interpreting data.

Literacy incorporating: Book “Four Seasons Make a Year.” Students will find similarities between their findings and the literary piece shared in class.

Duration: One hour and 20 minute lessons (to be repeated four times throughout the year; once per season). Breakdown: 15 minute intro, 15-20 minute field trip, 15 minute graph directions and graphing activity, 15 minute share aloud, 20 minute reading/discussing/predicting.

NGSS Standard: Ess2.D: Weather and Climate

Rationale: Students in Kindergarten should have a positive science interaction despite the lack of a science presence noted on NGSS standards. This lesson provides student the opportunity to make a connection with information already learned to the term “science” and begin to have a formal understanding of what science is and the topics included in the category of science. This is a basic lesson that utilizes inquiry with a hands on graphical interpretation of climatologically relevant data.

Activity:

1. Ask students to think about what their favorite season is and why. Have each student answer this question to the class. (Students can change their mind throughout the year!)

2. Ask students what season they think it is right now. How do they know- ask them for specific evidence? (Write answers on smart board or oversized post-it).

3. “Field trip” to school garden, courtyard or playground. Think of a safe location where students can observe and collect data (fallen leaves, flowers, seeds, bugs, weeds, snow, icicles, grass, soil, etc). Provide students with solo cups or other inexpensive collection dish. Allow students to work in pairs for 5-7 minutes.

4. Gather group and have a seat- ask students what they observe about the season.

5. Return inside to graph data. (Use sample on sheet 2 for students to make a multi-season graph. Make on large poster board that is pre-drawn or printed on 11X18 papers or larger.) Students will work in pairs to glue (graph) items in their appropriate box. Note: Have students draw anything living/mobile or that can melt and return outdoors.

6. Read “Four Seasons Make a Year.” Ask students what parts of the story correlated to their experience today. (Define Correlate to students)

7. Ask students to predict what may happen when they go on their field trip next season. Write down predictions and save (on same smart board presentation or large post-it)
### Seasons Graph

**Evidence**

<table>
<thead>
<tr>
<th>Evidence</th>
<th>Summer</th>
<th>Fall</th>
<th>Winter</th>
<th>Spring</th>
</tr>
</thead>
<tbody>
<tr>
<td>Leaves</td>
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<td></td>
<td></td>
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</tr>
<tr>
<td>Flowers</td>
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<tr>
<td>Soil</td>
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<td></td>
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<tr>
<td>Grass/Weeds</td>
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<tr>
<td>Snow/Ice</td>
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<td>Other</td>
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<td>Other</td>
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**Grade 2: What makes the seasons change?**

**Wind and Air Pressure Lab**

<table>
<thead>
<tr>
<th>NGSS Standard: Ess2.D: Weather and Climate</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Science Concepts Explored:</strong> Air Pressure, wind, temperature gradient.</td>
</tr>
</tbody>
</table>

**Background required:** Students should have some experience with planetary rotation, earth’s tilt and orbit.

**Duration:** 1 hour if students are working in groups, less if all activities are done as a class. NOTE: Stations 1 and 2 are demos to be completed by teacher only. Can be done as groups move through stations (recommended) or as a class. If done with groups an aid or additional teacher should be present to monitor other groups (combine classes if necessary).

**Rationale:** Students will build upon their basic understanding that seasons exist to understand why we have them and what makes the changes in seasons occur. This lab will allow students to learn that air is in fact composed of something. Further, that masses of air like to stick together. This will lead to the understanding that wind is made from different air masses attempting to stick together (and in turn, divert the other mass).

**This lesson relates to New York State Earth Science Standard:** 2.1i Seasonal changes can be explained using concepts of density and heat energy. These changes include the shifting of global temperature zones and the shifting of planetary wind.

**Background:** Ask students what they remember about seasons from kindergarten and their own life experiences. Ask a few students to share specifics. Discuss the various aspects of the seasons.

Ask students:

1. Why do we have Wind?
2. What is Air Pressure? (Note: Students will have ability to guess only about the two words as separate pieces- do not expect correct answers yet!)

Allow students to work in pairs and discuss this answer for 2-3 minutes. Allow students to share with the class.

**There are no wrong answers- Students will answer these questions again based on their findings from the experiments below.**
Station 1: Egg in a bottle

Supplies:

1. Hardboiled egg, shell removed
2. Glass drinking bottle (SoBe, Starbucks Frapp, anything with a mouth width slightly smaller than egg)
3. Tissue paper or paper towel
4. Wooden matches
5. Safety Goggles/Lab Coats

Discussion: Ask students why a fire burns. What “nutrients” or what does it need to burn? (hopefully one will respond with oxygen! If not, provide this information).

Begin to have students start asking new questions of their own based on the last two. Write the questions down or have an aid write them while you are discussing them. After 2-3 minutes, try to guide students to ask: If air is made of anything or what the “ingredients” of air might be? Can these ingredients be changed? (Do not answer the last 2 questions)

Directions: Do as a Demo only! Place tissue paper or paper towel in the bottom of the clean and dry glass bottle. Light 2-3 matches at once and drop in, igniting the paper towel. Immediately place the egg on the top of the jar.

(Note: The egg will get sucked in as result of the air pressure. The oxygen was removed from the bottle as the fire used it to burn, thus creating a downward pull of the air!).

Discuss: The egg was pulled u\into the bottle because the fire used up the oxygen in the air in the bottle. This made the air mass ‘try to pull’ more oxygen in. In turn, the egg had to be pulled out of the way. The bottle itself did not collapse…why could this be?

Station 2: Air Masses Exist…and Stick Together

Supplies:

1. Morton Salt container
2. Tea light
3. Matches

Directions: Place a tea light 2 inches behind a large salt container (such as Morton’s). The salt container and candles should be on lab table or desk, towards the front. Make an “x” with tape on the floor 3 feet in front of the desk/salt container so that it is in between the X and the tea light.

Ask students if they think they can blow the tea light out standing on the X with the container in the way-students must be level with the container! (Cannot try to blow over it). Discuss possible answers.

Light tea light and allow students to blow out the candle. (Note: Students will be able to blow it out! Reason: air travels in masses (moisture, temperature, etc that like to stay together. The air exhaled from the student wrapped around the jar can came together to extinguish the candle).

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Station 3: Air “stuff” exists again!

Supplies:

1. Juice glass
2. Bowl of water that is 4-5” taller than the glass
3. Paper Towel and tape

Discuss that the class has witnessed two things happening so far. First, we saw that the air pulled the egg into the bottle because the oxygen was being used up.

Station 4: Air “particles” exists…Part 3!

Supplies:

1. Drinking straws, cut in half without flexible neck.
2. Potatoes (1 for every 4 students)

Directions: Discuss with student that we have already seen that:

1. Air can change…It made of different “stuff.” If some of that “stuff” is taken away (like the oxygen was in the first experiment) it can create air movement.
2. Air moves together…It likes to stick together with other air that has similar properties (temperature, moisture, etc)
3. He “stuff” in air must have some sort of solid material in it, because it kept the water from reaching the paper towel.
4. This “stuff” is known as particles! The movement is known as pressure.

Allow each student to try to puncture a potato with a drinking straw. (Use 1 potato for every four students). Next, direct students to try again, but the second time they must cover the end of the straw with their finger. Students will see that when they out their finger over the back, the straw goes into the potato much further. This is because it is trapping the air in the straw (and its particles) and making the straw have a greater force.

After all stations have been completed together, work with students to answer the following discussion questions.

Discussion Questions:
1. Is air “nothing?”
2. Do you think air has mass?
3. Why do air masses travel together?
4. What is air pressure?
Lab: Air Pressure

**Background:** In kindergarten, we learned about the seasons. We know that there are four of them and that each has something special and distinct. The main reason that we have seasons is because the earth is tilted 23.5 towards the sun. Pretty cool huh?! That tilt creates warming and cooling as Earth orbits (goes around) the sun. Then, our air to becomes warmer or cooler, depending on the season. Let’s take a close look at what exactly air is and how it plays a role in the seasons as well.

**Here we go: Let’s see what we can find out about air!**

**Station 1**

Observe what happens to the egg!

What could have made this happen?

**Station 2**

**Task:** Place the container of salt in front of the candle and light it. Leaving the salt container between yourself and the candle, try to blow it out.

**Supplies:** Salt Container, tea light, matches.

Were you able to blow out the candle? ____

What does this tell us about air movement?
Station 3

Task: Place a paper towel in the bottom of the cup, and secure with tape. Turn the cup upside down and place underwater just enough to submerge the cup. Do this with the cup straight down. DO NOT TIP THE CUP!

Did the paper towel get wet? _____

What does this tell you about the mass and density of air?

__________________________________________

Does this mean that the density of air is greater than the mass of water? Justify your answer.

__________________________________________

Station 4

Task: You must try to poke the straw into the potato. Try this two ways:

(1) Cover the back of the straw with your thumb while trying to poke the potato
(2) Do NOT cover the back of the straw with your thumb while trying to poke the potato

Which way allowed the straw to move further in the potato?

______________________________

When thinking about air particles, why do you think this happened?

__________________________________________
Class Questions

Do you think temperature has an effect on the density of water? Explain.

Do you think that temperature has an effect on the density of air? Explain.

Group Discussion: Has anyone been to Lake Ontario after it has “turned?” Why does this phenomenon happen? How is it similar to moving air masses?

Higher-Level thinking: What is affected when the Lake turns? Does the lake play a role in the climate of Rochester/Upstate New York?

Draw a picture about what you learned about air particles today
Grade 5
A. Building a Weather Balloon

NGSS Standard: Ess2.D: Weather and Climate

Science Concepts Explored: Weather (precipitation, cloud cover, temperature, wind speed, wind direction), Laboratory skills (following multi-step directions), ability to communicate scientific findings, sorting, graphing/plotting scientific information. Engineering: determine what type of instrumentation is appropriate, how to determine amount of life required to displace mass, building a stable structure.

Duration: 2 hours total plus time to release balloons and record data (about 30 minutes). Students must then watch videos recorded (2 minutes) and be allowed time for discuss observations and plot data. Recommended: spend 30-45 minutes a day for 3-4 days.

Rationale: Students in grade 5 revisit Weather and Climate in Earth’s System studies according to the NGSS standards. This lesson builds upon skills taught in second grade while expanding a student’s ability to use engineering skills in science. This lesson will help students understand the importance of proper weight calculations in science, the ability to use various methods of data collection and allow students to gain an understanding of how weather indicators are studied in the field Meteorology. This lesson relates directly to high school standards. This is part of a three-lesson series that will also include students creating weather maps and determining a weather report based on weather station data.

Supplies:
Helium Tank
High Density Balloons
Popsicle Sticks
Pipe cleaners, Crepe Paper
Glue, rubber bands, tape
Thermometers
Parent volunteers with cell phones capable of recording video.
Congratulations! You have been selected to work on an elite team of engineers. We need to find a new way to collect data from a vertical distance of 50 feet above the ground. We need to record this vertical distance to see how views can be impacted with changes in height, we need to take the temperature at the ground level and at 50 feet high and we need to determine if there is any wind at a height of 50 feet above ground level.

Your task: Design an instrument that can determine all of those things.

The items you may use are:

- Balloons
- A helium Tank (ask for help from your teacher)
- Popsicle Sticks, Pipe cleaners, Crepe Paper
- Glue, Rubber bands, Tape, Ribbon (300ft spool)
- Thermometers
- A cell phone (parent volunteers, Thank you!)

Note: If filled with Helium, the balloons can carry exactly 2.8 pounds of weight.

Sketch what you and your team will build
1. How will you keep your device from blowing away?
2. How will you bring your device back down to the ground safely?
3. How will you make sure the cell phone will not break?
4. How can you be sure the cell phone will record its journey?
5. How can you be sure the balloon only goes up 50 feet?

How much do items weight that you will want to lift? MASS them using the scales located on the back counter. Record the weights here:

_____________________
_____________________
_____________________
_____________________

Can the balloon support the weight you plan to lift? ______

How do you know? ________________________________
______________________________
______________________________

If “yes” have teacher initial here________ and build your device

If no, revise your plan. List revisions here:

______________________________
______________________________
______________________________
______________________________
Today is the Day for Lift-Off!!

What do you expect to happen to the view of the recording as the balloon ascends (goes up)?

Draw what you expect to see at 4 feet, 20 feet, and 50 feet.

Now: Launch your balloons! When the reach 50’ in height, count to 15 then slowly bring the balloon back to the ground.

Take recordings:

What was the temperature at ground level? _____  At 50’ (it will be what the thermometer reads upon returning) _____

Was there wind at ground level? ___________  Wind at 50’? ___________.

How do you know?

________________________________________
Let’s watch our videos!

When you are done, answer the following questions in your group with your parent volunteer. Be prepared to share some of your answers with the class.

1. What changes as the balloon went higher?

2. Did the images look the way you expected them to in your drawings? What was the same, and what was different?

3. What would scientists use balloons to study?

4. Can you think of anything that can go higher than a balloon? List Them here:

   __________________________

   __________________________

   __________________________

5. Why would scientists want to view the earth from really high above?

   __________________________

   __________________________

   __________________________
Grade 5
B. Weather Station and Weather Maps Lab

**NGSS Standard: Ess2.D: Weather and Climate**

**Science Concepts Explored:** Weather (precipitation, cloud cover, temperature, wind speed, wind direction), Laboratory skills (following multi-step directions), ability to communicate scientific findings, sorting, graphing/plotting scientific information, graphical interpretation of weather maps.

**Duration:** 2 hours total plus optional presentation time (about 2-3 minutes per student to show one aspect of their completed poster. For example, Student: “This is Denver and the temperature is 72 degrees today.”). Recommended to spend 30 minutes a day for 4 days.

**Rationale:** Students in grade 5 revisit Weather and Climate in Earth’s System studies according to the NGSS standards. This lesson builds upon skills taught in second grade while expanding a student’s ability to use engineering skills in science. This lesson will help students understand the importance of proper weight calculations in science, the ability to use various methods of data collection and allow students to gain an understanding of how weather indicators are studied in the field Meteorology. This is part of a three-lesson series that will also include students creating weather maps and determining a weather report based on weather station data.

**This lesson directly relates to New York State Earth Science Standard:** 2.1c Weather patterns become evident when weather variables are observed, measured, and recorded. These variables include air temperature, air pressure, moisture (relative humidity and dew point), precipitation (rain, snow, hail, sleet, etc.), wind speed and direction, and cloud cover.
Background

(10 Minutes) Smartboard presentation entitled: Weather Maps Introduction.

(Slides 1 and 2) Explain to students that Meteorologists are scientists who study weather and make prediction called a forecast. Meteorologists use tools to help make their forecast. The Weather Map is one of a meteorologists’ most commonly used tools because it helps them to understand current weather patterns. The weather map shows us fronts clearly. Fronts are “boundary lines” between two different air masses. The masses usually have differences in temperature and moisture content (humidity). The front line is where most precipitation occurs.

(Slide 3) Scientists are able to map fronts by playing connect the dots! The dots they connect are weather stations. A weather station contains information such as current temperature, dew point, wind speed and direction and current precipitation as well as other scientific data. By connecting weather stations with similar temperatures, meteorologist can learn where fronts occur. Because the temperatures are not always exactly the same, they often draw the lines between the stations. The lines they draw when connecting the lines are called: isotherms.

Fun Fact: many words in science have Greek roots, and Isotherm is one of them!

Iso= equal
Therm= temperature
So, literally, isotherm lines are “lines of equal temperature.”

Need to Know: Dew Point- a scientifically calculated number that relates to humidity (moisture) in the air. The closer the dew point is to the temperature, the more likely precipitation will occur.
Weather Station Model Lab

We will be making our own Weather Station Model that includes some of the aspects meteorologists use to predict the weather! Let’s look at them below.

Your Objective:
You will make your very own weather station model for a city of your choice using information of your choice. Once assembled, you will write a forecast using this information. Please use the following format:

   Name of City

1. Cloud cover
2. The temperature and dewpoint.
3. Wind speed and direction
4. Precipitation, if any

Supplies: Please ensure you have all supplies before you begin.

1. Poster Board
2. Cloud cover circle (or none of you would like a clear sky)
3. Wind direction piece
4. Wind speed pieces
5. Pre-cut numbers
**Group Practice:** Lets Draw lines at 60, 70 and 80 degrees!

Now, Try to draw the isotherms for this map independently. You may ask your partner for help if needed!

*Use the following colors: Red: 30°, Blue 40°, Yellow 50°, Green 60°, Orange 70°.*
Pull up weather map on the smart board and allow students who drew the Isotherms correctly to come up and draw them on the map.

Ask students the following questions:
1. Is the country warm or cool today?
2. What season could it be?
3. How many air masses are present on this map?
4. Where do you think precipitation may be occurring? Why? (Have students come up and point to map. Draw zig-zags on the front line)
5. Where do you think the front is present? (It is the zigzag line from question 4)
6. How long do you think the front will be in this area?
7. What direction does it look like the front it moving in? (North south east or west? Answer: west. Most weather moves westward across the United States).

Homework:

Write one question you have about weather maps in your homework folder. Work with your parents this evening to find the answer!
C. Creating a Weather Report

NGSS Standard: Ess2.D: Weather and Climate

Science Concepts Explored: Weather (precipitation, cloud cover, temperature, wind speed, wind direction), Laboratory skills (following multi-step directions), ability to communicate scientific findings. Literacy Incorporation: Ability to communicate scientific findings in a clear and concise manner that is easily understood by the general public.

Duration: 2 hours total plus optional presentation time (about 2-3 minutes per student or less of ask students to only show one aspect of their completed poster, i.e Student: “This is Denver and the temperature is 72 degrees today.”). Recommended to spend 30 minutes a day for 4 days.

Rationale: Students in grade 5 revisit Weather and Climate in Earth’s System studies according to the NGSS standards. This lesson builds upon skills taught in second grade while expanding a student’s ability to use engineering skills in science. This lesson will help students understand the importance of proper weight calculations in science, the ability to use various methods of data collection and allow students to gain an understanding of how weather indicators are studied in the field Meteorology. This is part of a three-lesson series that will also include students creating weather maps and determining a weather report based on weather station data.

This lesson directly relates to New York State Earth Science Standard: 2.1g Weather variables can be represented in a variety of formats including radar and satellite images, weather maps (including station models, isobars, and fronts), atmospheric Cross-sections, and computer models.

Supplies:
ALL student-made materials from Lesson 5B
Video Cameras/Tablets with cameras from School Library

Directions:
1. Students will work in teams and find the averages of their individual weather stations (using mathematical sills). They will use the attached weather station model to create a final weather station. Precipitation will be determined based on the dew point temperature in relation to the air temperature.

2. Students will then create and record a 1-2 minute weather report. They will include all pertinent information from their weather station. A one paragraph written summary will be attached to their new weather station summarizing the current weather.

Optional STEM work: (Technology) Upload the video in technology class and add in effects such as a moving weather map, precipitation, etc.
STUDENT WORKSHEET

Names________________________________________

Weather Station for (city): ________________________
REFERENCES


Judson, Eugene. When Science Counts as Much as Reading and Mathematics: An Examination of Differing State Accountability Policies. *Education policy analysis archives* [S.l.], v. 20, p. 26, sep. 2012. ISSN 1068-2341.


