Building investigative skills and critical thinking for middle school students through inquiry based science lessons

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BUILDING INVESTIGATIVE SKILLS AND CRITICAL THINKING FOR MIDDLE SCHOOL STUDENTS THROUGH INQUIRY BASED SCIENCE LESSONS

Action Thesis Submitted in Partial Fulfillment of the Requirements for the Degree of Master of Arts in Education

California State University Monterey Bay
2014

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BUILDING INVESTIGATIVE & CRITICAL THINKING

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Abstract

This research analyzes the results of implementing inquiry based science lessons in a middle school classroom to determine if students build critical thinking and inquiry skills. Additionally, the impact of inquiry lessons on my own teaching methods and on student attitude towards science learning was measured. Conclusions have been drawn through analysis of data from pre and post intervention student questionnaires, rubric scoring of student work, as well as analysis of the inquiry lesson plans and impact on teaching methods. Through implementation of specifically designed inquiry based activities requiring students to build upon previous knowledge and providing opportunities to actively construct understanding of science and the natural world, participants showed a minor increase in critical thinking and inquiry skills. Attitude towards science was seen to be more positive after the implementation of the inquiry based lab activities in the experimental group of students. Teaching methods were found to have shifted during inquiry based activity surrounding time management as well as teacher focus and control during student activity.
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CHAPTER 1

Introduction

“The future is in the hands of those who explore.” This quote from Jacques Yves-Cousteau, famous underwater explorer, proposes a challenge for generations to come. For educators, providing opportunities for students to discover new ideas and ways of knowing makes the quote from Yves-Cousteau a compelling reality. In fact, educators and science educators in particular, would like to leave the world in good hands, to be led by individuals who have the ability and skills to continue exploration; exploration of not just the natural world, but the ability to explore a problem, to critically think through an issue, and be able to analyze the conclusions that they draw.

Since the implementation of No Child Left Behind in 2001, time spent on science education in the elementary classroom has dropped. Impacts have been felt in the classroom as many teachers devote more time to reading and math activities. Reduction in class time for science in order to teach more reading and math has been documented in previous studies, resulting in a narrowing of curriculum, denying students the foundation they need (Griffith, 2008). Early exposure to science in education is important because science encompasses real world problem solving and introduces inquiry skills to solve those issues (Eshach & Fried, 2005). Not only has time for science education decreased since NCLB was introduced, but it also has denied many students the basis they will need for critical thinking and inquiry skills as they progress through school.

Scientific knowledge is not just an individual practice, but a social one (Asoko, Driver, Leach, Mortimer, and Scott, 1994). This thinking mirrors previous theories of development in
children and social construction of knowledge (Vygotsky, 1978). In the science classroom in particular, the theories and methods surrounding constructivism have proved effective in conveying inquiry and critical thinking skills to students throughout the grades. According to Piaget (2003), the developmental stages that children go through in order to integrate knowledge into their schema, or explanations of the world, are important to consider during science learning. Inquiry based lessons use these developmental stages in order to introduce critical thinking and inquiry to students and encourages students to construct their own knowledge. This type of teaching is quite different than the mandated scripts and curriculum set forth by NCLB. To counteract the failings of NCLB and to accent theorists such as Piaget and Vygotsky, all students should have access to a meaningful science curriculum that helps them each gain experience with science inquiry and strengthen their critical thinking skill. By giving students opportunities to experience science in different modalities, students of varying ability can have meaningful science experiences upon which to build their inquiry skills. Within the field of science education in particular, the gap between ethnic groups and their success on state exams has persisted since the implementation of NCLB, a program designed to close this gap (Dorph, Shields, Tiffany-Morales, Hartry, and McCaffrey, 2011).

In the near future, the Next Generation Science Standards and Common Core Curriculum will bring a sharper focus on critical thinking and inquiry skills. This research will show whether inquiry based learning in the middle school science classroom is effective at giving students a knowledge base to build upon as they continue through the science curriculum. As a result students will be able to tackle a problem using critical thinking skills, conduct a scientific inquiry using the scientific method, and analyze theories, issues, and ideas using scientific thought and deduction.
More research is needed at the middle school level to determine if in fact these students who are lacking in basic critical thinking and science inquiry skill can begin to build such a foundation when given the tools. Aligning the science curriculum with constructivist and inquiry-based teaching methods and giving students opportunities to experience hands-on activities to facilitate science learning is necessary.
Problem Statement

The implementation of No Child Left Behind (NCLB) has significantly changed elementary education over the past 12 years. Goals of NCLB included a focus on advancing the reading and arithmetic skills of students. This focus was communicated to classrooms through the use of scripted lessons and mandated high-stakes testing in the reading and math areas. An unfortunate side effect of NCLB has been less time spent on scientific inquiry and investigation in elementary classrooms (Milner, Sondergeld, Demir, Johnson, & Czerniak, 2011). To compound the problem, constructivism, a preferred method in which to teach science and inquiry lessons has been virtually dismissed by educators (Cakir, 2008, Colburn, 2000, Lawson, 1985). There has been ample research during the implementation of NCLB indicating that prescriptive methods are not aligned with constructivist teaching (Drake & Huglin, 2011). In light of these facts, students who have passed through elementary school with little experience in science, inquiry, and critical thinking skills have a weaker foundation in these areas when presented with middle school science tasks and subjects. Therefore, in order to build the background and foundation students need, the middle school science curriculum must be supplemented with both systematic inquiry and constructivist approach to introducing, investigating, and carrying out scientific investigations that require critical and higher ordered thinking.
Purpose of Study

The present study is designed to examine the effect of implementing inquiry-based teaching methods in the middle school science classroom. Students who have had little experience with scientific inquiry and critical thinking skills in their elementary education have not constructed a knowledge base upon which to build when they enter middle school science classrooms, which contain a more complex, involved, and diverse curriculum. In order to remedy this situation and give students the skills and experience needed to be successful in scientific inquiries, changes to the middle school science curriculum need to be made. A constructivist approach will be used to ensure that students have the freedom to derive meaning from science teachings and interaction with science methods, materials, and the real world.

For example, in teaching students to understand the process of pollination during angiosperm reproduction, a constructivist-based inquiry lesson would include an introduction event in which students would write or verbalize their current knowledge about how pollination occurs. In partners or small groups, students would be given the task of building a basic, wire model of what they believe an efficient pollinator might look like. Using this prototype, student would build their ‘real’ pollinator out of provided materials (pipe cleaners, tape, toothpicks, etc.). Students would conduct an experiment using their newly designed pollinator, collecting real pollen from a perfect flower. Their previous knowledge of pollinators and the process of pollination would then be either challenged or affirmed by their experiment. The lab is specifically designed to get students to examine different aspects of their knowledge and hypothesize which characteristics are needed for an efficient pollinator. Extensions of these ideas reach to angiosperm reproduction and the specific structures and functions of a flower. Students will be directed to concrete answers in following lessons in which they view video, lecture, note
taking and partner activities in order to integrate this new information of sexual reproduction in flowers and how it occurs. Students will then revisit the flower and pollinators in a lab activity, using careful observation to identify the different parts used in reproduction to see their structure and function within the flower.

Using inquiry based lab activities such as the one described above, this research will endeavor to show whether these types of lessons give students a positive view of science and provide students with a knowledge base to build upon as they continue through the science curriculum. As a result students will be able to tackle a problem using critical thinking skills, conduct a scientific inquiry using the scientific method, and analyze theories, issues, and ideas using scientific thought and deduction.
Research Questions

1. What will be the impact of changing my science teaching from a didactic to a constructivist-based model on my development as a teacher?

2. Will the science lab report scores of my 7th grade students taught using inquiry-based methods be higher than scores of students taught using traditional didactic methods?

3. Does implementing inquiry based lessons give middle school science students a more positive attitude toward science?
Theoretical Model

How one constructs knowledge has been the study of many theorists, psychologists, and researchers. In the examination of science education specifically, the lack of exposure to scientific inquiry and critical thinking at the elementary level has left some students without the foundation on which to continue to build knowledge as they age and graduate through the education system. Thinking about how knowledge is constructed, how knowledge is developed and appropriate applications of these theories is a current pursuit of research.

The theory of constructivism and the methods of constructivist teaching have long been a foundation in science education. Jean Piaget spent years studying child psychology and the construction of knowledge in children. One of his central pursuits was to dissect the way in which knowledge is constructed by the learner. Through his observations, the theory of constructivism emerged, stating that children pass through particular operational stages in which they acquire knowledge and build upon previous ideas. In the article “Development and Learning” (1964), Piaget identifies that knowledge is something that is constructed by the learner. The child is able to perform certain activities that Piaget terms “operations,” which consist of an action from the learner. He outlined four stages of development: sensory-motor, pre-operational, concrete operational, and formal operational (Piaget, 2003). Although Piaget himself did not apply many of his theories directly to the field of education, his theories have waxed and waned in popularity with educators since the 1970s.

Lev Vygotsky argued that the status of mental development in children can be characterized by what he termed their “zone of proximal development” (1978). It is the independent activity of the learner that indicated their zone of proximal development, or ZPD. Learners may be the same age, be able to perform some of the same modeled tasks, but differ in
their ability to do so independently of social learning situations. Vygotsky saw this measurement as invaluable to researchers endeavoring to determine learning and capabilities of children. In his paper “Interaction Between Learning and Development” (1978), Vygotsky describes that an important aim of study should be “to show how external knowledge and abilities of children become internalized.” This gives not only psychologists, but also those in the field of education a reason to investigate this particular phenomenon.

Driver and Easley (1978) connected the ideas of constructivism, education, and how the learner constructs knowledge by reviewing multiple studies. They argued that the demands of curriculum do not always match the cognitive level of the student, and this should be taken into account when developing science curriculum. They cite further research that indicates training in the logical operational skills is necessary to deepen learning of scientific concepts. This would argue for science teaching to begin at an early age in order to build the foundation that students will need to understand and construct new ideas from in their future schooling. Driver and Easley concluded that Piaget's theories of childhood learning and development are critical ideas in science education. Learners need a certain basis upon which their new ideas can form.

Asoko, Driver, Leach, Mortimer, and Scott (1994) indicate that the nature of science includes a projection of human ideas upon nature in an endeavor to explain phenomena. Scientific knowledge is both individually and socially constructed, including exposure to scientific concepts and ideas as well as physical activities in which they can engage and apply their knowledge. This, state the authors, is the challenge of the science curriculum.

An outgrowth of the underlying constructivist theories can be seen in classrooms today. Colburn (2000) applies the ideas of constructivism to science education and Piaget's theory of
learning and knowledge acquisition by indicating that students must experience some discrepant event or make a prediction in order to begin to access their previous knowledge and apply it to the scientific concept being presented. In an endeavor to begin science learning (and teaching) at an early age, Gould, Weeks, and Evans (2003) advocate for an early education program entitled the Early Childhood Acceleration Program (ECAP®R). This type of program lays the foundation for critical thinking and scientific concepts at an early age. It would be safe to assume that students participating in this type of program would be more than prepared for a middle school science curriculum. Eshach and Fried (2005) advocate for early childhood education, citing that it will only help to build the understanding of students and enhance their critical thinking skills with the benefits of helping them make sense of the world around them, creating a more informed individual. However, they set out to answer the question of motivation for young students to learn science. They cite two basic reasons for elementary science education. First, science is about the real world, and second, it lays the foundation reasoning skills.

Researchers mentioned previously are currently active in this area, building upon the theories described, determining the appropriate age to begin science instruction and the preferred methodology. However, more research is needed at the middle school level to determine if in fact these students who are lacking in basic critical thinking and science inquiry skill can begin to build such a foundation when given the tools. Aligning the science curriculum with constructivist teaching methods and giving students opportunities to experience hands-on activities to facilitate science learning is necessary.

Constructivist approaches have endeavored to engage learners in critical thinking in the classroom. In order to measure educational objectives and curriculum goals, the Taxonomy of Educational Objectives, or Bloom’s Taxonomy, as it has come to be widely known, has been
used by educators for many years. In order to measure the cognitive, affective, and psychomotor domains, the taxonomy tracks and catalogues changes as learners progress through a series of objectives. This has been a useful tool, allowing educators to easily communicate with one another about their educational objective and outcomes with appropriately defined terms (Bloom, Engelhart, Furst, Hill, & Krathwohl, 1956).

Although Bloom’s Taxonomy has undergone changes throughout the years, Forehand (2005) states that it remains an excellent tool. Though the framework has been revised, in any form, Bloom’s Taxonomy is an important device for educators when it comes to the measurement of critical thinking. Krathwhol (2002) discusses the original intent and usage of Bloom’s Taxonomy in order to measure student abilities and skills as they move from one level to the next. The learner must master one level and associated skills before moving upwards on the scale to a more complex task. This has been valuable to educators who endeavor to align learning goals, curriculum, and state or national standards. The taxonomy also provides teachers with a tool in which to measure learning objectives and student skills in the classroom.
Researcher Background

I have been interested in science my entire life. When I was ten years old, I knew I wanted to study biology. I attained a Bachelor of Science degree in the field of Biology, with an emphasis on invertebrate and marine biology from Western Oregon University in 2006. Upon graduation, I worked for Oregon Trout, coordinating volunteers for the Salmon Watch program, organizing trainings and field trips for students to view salmon spawning. This was one of my first close experiences with outdoor education. I very much enjoyed the outdoor teaching experience and applied for similar jobs. For five years I lived on Catalina Island working for the Catalina Island Marine Institute (C.I.M.I.) at Toyon Bay as a Marine Science Instructor. I helped students have close encounters, investigations, and adventures with nature and the ocean. Since then, I have moved to the Monterey Peninsula to continue my education in the field of education. I received my Single Subject Teaching Credential in Biology from California State University at Monterey Bay in 2012. As I continue to further my education, I endeavor to find the best way in which to communicate the importance and wonder of nature to young people.

My job as a middle school science teacher is to find a way in which all students can feel that they understand science to the best of their abilities. Science education has taken a backseat in many elementary classrooms as they struggle to meet the requirements of No Child Left Behind. The focus is directed to math and reading skills, leaving science to be a subject that is either “squeezed in” or neglected altogether. Having no previous scientific inquiry experience leaves students between a rock and a hard place as they enter the middle school science curriculum. As a result, many students feel that science is a mystery, difficult to understand and interpret. Not experiencing critical thinking and scientific inquiry skills in elementary school
leaves students at a disadvantage when they attempt to understand much more complicated concepts, such as evolution or cell biology.

Constructing ways to present students with information, have them experience concepts, and providing them with ways to demonstrate their knowledge is key to science education. I have been increasingly interested in the ways in which student assimilate knowledge that is presented in class. Many students come into the classroom with previous explanations about the world. Some of these are correct, some are misconceptions. How then, do I, as the teacher, construct lessons in the most helpful way to get students to understand and investigate these scientific concepts? These are the questions that have put me on the path to investigating the ways in which knowledge is constructed in the learner.

In my research regarding constructivism and how a student most effectively builds knowledge, particularly as it is applied to the science classroom, the issue of students being ill prepared for the middle school science curriculum was occupying the forefront of my thoughts. Even if students are missing experiences in elementary school that would serve to build their scientific inquiry skills, can these foundations be built in the middle school curriculum? How might inquiry based lessons be implemented at this level in the science classroom? In order to help my students who will be entering my classroom with little to no foundation in scientific inquiry and critical thinking, these types of experiences may be very helpful.

The subjects of the proposed study will be students in my 7th grade Life Science classroom. As a teacher, my job is to try to support, scaffold, and encourage learning for students of all levels and ability. In order to give them the foundation they need to tackle tough scientific questions and concepts, inquiry-based activities embedded in the science curriculum may be very
helpful. The drive I have to understand how students build knowledge, how I can best work with
that to help them build their knowledge base, and how I can give them the critical foundation
needed to succeed in their science education is why I am so interested and invested in this
project. As a previous outdoor educator, I led many students in lessons where they were
experiencing science and thinking about the natural world in a different way. This is the type of
thinking and experience I would like to bring into the classroom. I am confident that I will be a
better educator because of this inquiry, imparting the wonder of science and the natural world on
students in the most effective way possible.
Definition of Terms

**Assimilation**: acknowledgment of a concept present in schema by the learner.

**Accommodation**: integration or reworking of schema to incorporate new knowledge.

**Bloom’s Taxonomy**: a classification of learning objectives used to define different levels of cognition.

**Constructivist, constructivism**: Theory explaining how knowledge is constructed in the brain through experiences.

**Critical thinking**: Actively and skillfully conceptualizing, reasoning, evaluating, applying, and analyzing information.

**Curriculum**: Collection of subject matter taught to students, including but not limited to established standards.

**Didactic**: involving lecture and textbook instruction rather than demonstration and laboratory study.

**Discrepant event**: teaching events in which the student is an active participant, causing disequilibrium in the present schema of the learner.

**Disequilibration**: the appearance of events or ideas that do not fit into existing schema.

**Foundation**: The supporting layer of a structure, in this case, the core knowledge and skill upon which to build new knowledge and skill.

**High stakes testing**: Testing with important consequence for the test taker.

**Inquiry Based Lesson**: a pedagogical method that poses questions, problems, or scenarios, using a social context to build knowledge from experience, instead of presentation of facts.

**Laboratory activity**: An activity designed for scientific experimentation or research.

**Method**: a systematic way of accomplishing something, a means of procedure.
No Child Left Behind: U.S. Act of Congress to reauthorize the Elementary and Secondary Education Act, in order to help disadvantaged students, supporting standards based reforms.

Prescriptive curriculum: Specific learning programs required by either the state, district, or school.

Scientific inquiry: The various ways in which the natural world is studied and propose explanations based on observation.

Schema: the pattern of thought or behavior a learner uses in order to explain the world around them.

Zone of Actual Development: the area of learning a student occupies based on what they can do on their own, without guidance of peers or adults.

Zone of Proximal Development: the area of learning a student occupies based on what they can do with the guidance of peers or adults.
CHAPTER 2

Literature Review

Introduction

Within this review of the literature, the essential themes surrounding constructivist and inquiry-based teaching and learning will be explored. These include the impact of inquiry-based teaching on my practice as a science teacher, the lab report scores of students, and a measure of student attitude towards science both before and after the implementation of inquiry-based lessons. Specifically, my research aims to discover what issues surround the design, integration, and implementation of inquiry-based science laboratory activities, and how these impact my own practice as a 7th grade Life Science teacher. I will be measuring the lab scores of students during four inquiry-based lab activities to determine their level of critical thinking and inquiry skill. These scores will be compared to students taught with traditional, didactic methods to discern any differences that might be present. Students will also be communicating their attitude towards science learning before and after the implementation of the inquiry-based lessons in order to determine if a change in attitude has taken place. Specifically, I am endeavoring to answer the research questions stated below.

1. What will be the impact of changing my science teaching from a didactic to a constructivist-based model on my development as a teacher?

2. Will the science lab report scores of my 7th grade students taught using inquiry-based methods be higher than scores of students taught using traditional didactic methods?

3. Does implementing inquiry based lessons give middle school science students a more positive attitude toward science?
Sequence of the Review

First, I review studies regarding the history of constructivist theory, how this is applied to education, specifically to science classrooms and the shift away from constructivist theory due to the implementation of No Child Left Behind and the impact of this change on the elementary science classroom. Second, I investigate studies regarding inquiry-based teaching, which is rooted in constructivism, the implementation in the science classroom and impact of this pedagogy on the teacher. Third, studies regarding the impact that inquiry-based teaching has on student attitude will be reviewed.

Constructivism and Education

History of constructivist theory. Piaget and Ausubel are two of the major theorists behind constructivism. Within their view, a learner can recall and remember knowledge more easily if it fits into an existing schema, which include the learner's explanations of the world and the way in which it works. Information that does not integrate into this schema is more difficult to recall and remember. It is useful to think of changes in the knowledge state of a learner in terms of assimilations, accommodations, and disequilibrations (Cakir, 2008).

Assimilation is the acknowledgment of a concept in existing schema, accommodation is the integration or reworking of schema to incorporate new knowledge, and disequilibration as the appearance of events or ideas that do not fit into existing schema or beliefs. Piaget reasoned that learners most effectively build understanding in a parts-to-whole way, constructing knowledge from pieces that are then integrated into a schema (Cakir, 2008). These schema help to explain the nature of the world and provide a basis of understanding for the learner.
**Constructivist theory as applied to science education.** Applied directly to the field of science education, there are four stages of development: sensory-motor, pre-operational, concrete operational, and formal operational. The sensory-motor stage occurs first, in which a learner develops the idea of permanence in objects. The pre-operational stage occurs next, which include the development of language. The concrete operational stage follows, where classification, spatial operations, and elementary logic develop. The fourth stage is the formal operational stage in which reasoning and the construction of new operations occur. The learner is now able to reason beyond the concrete, using hypotheses, equilibrating knowledge. Other factors that influence the construction of knowledge include experience, social transmission, and maturation (Piaget, 2003).

When examined closely, the developmental stages of concrete and formal operations are the areas in which a learner has the ability to work with models or abstract ideas, mirroring skills that are often used in scientific investigation. However, the demands of curriculum do not always match the cognitive level of the student, and this should be taken into account when developing science curriculum. Research indicates training in the logical operational skills is necessary to deepen learning of scientific concepts. “As with science itself, perhaps learning science proceeds not by the testing of one theory against the data, but by first making an imaginative leap which enables a new way of thinking about a problem to take place” (Driver & Easley, 1978 and Sjoberg, 2007).

Learners of science must be introduced to the field and its culture, with the teacher assisting. This connects to the concrete and formal operational stages described by Piaget, in that the teacher must be an instrument in the science classroom in order to foster scientific thinking,
providing students with opportunity and practice to develop through these stages (Asoko, Driver, Leach, Mortimer, & Scott, 1994).

A direct application of Piaget's theories about how learners construct knowledge can be seen in the science classroom. Knowledge is not something that is passively received, but instead actively created by the learner themselves. Learners come into science classrooms with preconceived ideas about the natural world based on their own previous experience and ideas. This existing schema will have an impact on the way in which the learner perceives and interprets science. Taking these pre-existing ideas into account can help a student to learn more effectively (Taber, 2006).

Not only do preexisting ideas influence a child's ability to learn, but each student has a varying ability to perform tasks independently of social learning situations. Each learner may be at a different stage of cognitive development, come into the classroom with different experience and schema. The development of the learner may not be in sync with the school learning and curriculum, as each student and subject vary from one stage of development to the next (Vygotsky, 1978).

No Child Left Behind: an educational shift from constructivism. No Child Left Behind (NCLB) was initiated in 2002 for use across the United States by the mandate of President George W. Bush. NCLB has been described as a political movement intended to reform education in the United States and raise proficiency levels in math and reading to 100% for students from third to twelfth grade by the end of the 2013-2014 school year. NCLB sets goals to which all children and schools must conform, with consequences for not meeting NCLB standards. The Adequate Yearly Progress (AYP) reports are a large part of school accountability
and assessment. Failure to meet the AYP standards set by NCLB can result in school funding being cut, replacing teachers and administrative staff, closing schools, and a host of other punitive measures (Shapiro & Thompson, 2008 and Braden & Schroeder, 2004).

Since the implementation of NCLB, there has been a shift away from constructivist methods in the classroom. Constructivist theory involves teachers helping students to alter their beliefs, while viewing teaching as instilling knowledge through meaningful activity, rather than giving students information to memorize. In order for constructivist teaching to occur in classrooms, certain elements are needed in the curriculum. These include discussion, lab activities, requiring concept application, strategic questioning, invention, sharing, and research conducted by the students (Colburn, 2000). The pressure and narrowed curriculum produced by the NCLB requirements has resulted in heavy emphasis on teaching methods that inundate students with information, expecting them to then reproduce that information in a high-stakes testing environment (Shapiro & Thompson, 2008).

Constructivist theory views learning as socially constructed, with the classroom as the central place for participation in the acquisition of knowledge. Constructivism uses inaccurate answers and ideas from students to modify curriculum and teaching strategy, while NCLB uses test scores to rate the effectiveness of the school, teachers, and students. Due to the requirements and consequences of NCLB, school administrative decisions are made with the consequences of NCLB in mind (Drake & Huglin, 2011).

**NCLB's impact in the elementary science classroom.** NCLB has had a strong impact on elementary science instruction. Minutes of instruction in the elementary classroom are dedicated to various subjects, but with the passing of NCLB, the most amount of time is spent on the
subjects that the NCLB high-stakes tests center around: math and reading. Science test scores are not included in the AYP score of schools. This exclusion of science test scores may cause some to view science as less important, causing science instruction to be cut by elementary teachers, either by the direct request of the administrators or by their own decision in order to increase instructional minutes spent on other subjects. Besides less time being devoted to science instruction, teachers also choose to not teach science due to lack of resources, a deficiency in materials, and little professional development or support for science teaching. This is concerning because elementary education is where students will gain the knowledge that they can later build upon. Students are effectively missing out on a foundation of knowledge on which they can build when they reach middle school, with teachers mistakenly assuming that students will be able to somehow catch up with their science learning in later grades (Milner, Sondergeld, Demir, Johnson, & Czerniak, 2011 and Griffith & Scharmann, 2008).

Due to the mandates of NCLB and the accountability and consequences schools face, the learner is no longer driving curriculum choices and implementation. Some have criticized NCLB for removing the individualization of curriculum for both teacher and student (Milner et al., 2011 and Shapiro & Thompson, 2008). Students repeating facts that are meaningless can cause the erosion of confidence in the student's ability to learn. Students cannot become independent in their learning and reasoning if they are continuously guided by dictatorial relationships with teachers. Teachers are meant to develop relationships with students that will foster discovery and learning in order to boost the child's confidence in their own construction of knowledge (DeVires, R., 2002).

In addition to the individualization of curriculum, a child with a developing brain needs to be emotionally engaged in the material before learning can occur. This is less likely to happen
in a classroom where the curriculum has been narrowed, with a teacher constrained by time forced to move students along at a predetermined pace. Students must be actively engaged in their learning, using many parts of their developing brain at once, fostering knowledge acquisition and exploration (Rushton & Jula-Rushton, 2008).

In California, only 10% of students regularly receive science instruction. In grades K—5, 40% of students receive 60 or fewer minutes of science weekly (Dorph, Shields, Tiffany-Morales, Hartry, and McCaffrey, 2011). These numbers express the need for California to begin science education in elementary school. Lack of time in the classroom, resources, and support are issues teachers and students currently face. Many of these obstacles have been put in place by the implementation of NCLB, requiring schools to focus more of their attention on reading and math skills, pushing science education to the background.

Since the implementation of NCLB, less science instruction has taken place at the elementary school level. Students need to have a foundation in science in order to build upon that knowledge later in life. This agrees with the theory of constructivism in that learners construct knowledge in a parts-to-whole way, using previous experiences and knowledge to explain the world around them (Milner et al., 2011).

**Inquiry-based teaching in the science classroom**

**Classroom implementation.** In order to do real science, one must have general knowledge of the domain as well as inquiry skill. These link theory and evidence for the theory, two things required in scientific endeavors. By putting students in situations in which they exercise their inquiry skills, theorize, and find connections between ideas, they develop these reasoning skills.
One possible setback to this idea includes the fact that students of the elementary age may not cognitively possess the skills in which to conduct scientific thinking. However, there have been identified “windows of opportunity” in the field of brain research that conclude young children of elementary school age are open and very receptive to new ideas and ways of thinking. As humans age, the introduction of new material becomes more difficult to assimilate into one's schema. This time should be taken advantage of by having elementary science education regarded as important and present in the classroom (Eshach & Fried, 2005).

How best then to teach science in the classroom? In order for a learner to have a conceptual change, certain requirements must be met. First, before accommodation of new knowledge can take place, the learner must be discontent with their current explanation. Second, the learner must be able to understand the new concept. Third, this new explanation must look credible to the learner. They must believe that it has merit and appears applicable to the issue at hand. Finally, this explanation can be extended to other areas (Gertzog, Hewson, Posner & Strike, 1981).

Many methods of teaching have been proposed in order to incite this conceptual change in students. The use of pre and posttests can help to determine student understanding of key concepts after the teaching unit. Conceptual change can be built out of learning events based on the principles of constructivism, building knowledge from previously existing ideas through social situations. To initiate these changes in belief, a number of strategies based on constructivist theory can be used including cooperative learning situations, questioning, wait time, demonstrations, and discussions (Colburn, 2000, Hewson, 1992, and Holtzmiller, 2008). However, the style of laboratory activity that students engage in will have an impact on their
overall learning outcomes. It is important to provide students with the concrete concepts that will influence their correct discovery of facts during their experiment (Hodson, 1990).

The Next Generation Science Standards (NGSS) are the upcoming standards in the elementary, middle, and high school sciences. As previously mentioned, NCLB has had a negative impact on science teaching in the elementary classroom, reducing or eliminating minutes of science instruction. In order to remedy this situation, there are many crosscutting concepts and core ideas across the NGSS. These include pattern observation, cause and effect principles, scales and proportions, systems and models, energy and matter, structure and function, and stability and change. The new standards are an endeavor to accomplish many goals, as they are aligned to the Common Core standards, which are making their own debut in classrooms soon. These new standards are designed to elicit more critical thinking skills and will be started at a young age (Bybee, 2013).

Many curriculum designs are specifically tailored to elicit critical thinking from students so they are able to investigate and attempt to solve scientific inquiry. By providing students with carefully designed teaching and learning events, involving students in the active pursuit of knowledge, the basic skills for scientific inquiry and critical thinking are built by the learner. The upcoming standards and changes to the middle school science curriculum will require students to use these inquiry and critical thinking skills. As mentioned previously, in order to integrate new information, the learner must be actively involved. This will be a challenge to science educators during the implementation of inquiry based learning in the classroom.

**Student critical thinking measurement.** A true science education means that a student has integrated knowledge of the subject and has not just memorized facts. Currently, the
California State Standards seem to emphasize the importance of student understanding and fact recall in the realm of science education. Although factual knowledge is important, depth of knowledge is also important (Manthey, 2006). Bloom’s Taxonomy, in either its revised or original form has remained a tool educators can use in order to assess student critical thinking (Forehand, 2005). Although Bloom’s Taxonomy has been revised, however, the original classification scheme is retained. The taxonomy, made of categories ordered from the simplest level, Knowledge, to the most complex, Evaluation (Bloom et al., 1956). These measurements show development of critical thinking from the concrete to abstract. Bloom’s Taxonomy lends itself as an important education tool when paired with educational objectives and student progress. Most educators endeavor to lift students to the Evaluation level, where they are able to incorporate their previous learning and experience. Bloom’s Taxonomy has long been used in order to measure student achievement and educational goals (Krathwohl, 2006). As previously discussed, education has seen changes from the implementation of NCLB to the impending Common Core and NGSS. As educators endeavor to integrate critical thinking activities into the classroom to prepare students for more in depth standardized testing and standards, the measurement of critical thinking will be important for educators to integrate into their daily observation of student work.

**Impact on science teaching.** Learning and teaching science must not merely be seen as an overview or reinforcement of previous ideas that the student has, but rather an introduction into the world of scientific thought and process. In this, teachers need to intervene and assist the student in discovering how to become in effect, a scientist, carrying out inquiry using techniques and strategies that are accepted in the scientific community. In order to successfully guide students through this type of learning, teachers must generate interest and focus on the lesson,
decide what methods and resources are needed, the skills that students need to complete the task, interpretation of results, and communication of these results to an audience (Hodson & Hodson, 1998).

Besides the careful planning of lessons by the teacher, the key skills in building inquiry need to be fostered during these activities. In order to support student learning, certain elements need to be present in the pedagogy. These include schemata, concrete preparation, cognitive conflict, social construction, metacognition, and bridging. Schemata refers to Piaget's stages of development and learning; what students will use in order to make sense of the activity. Concrete operation references the fact that the beginnings of the activity are not out of the realm of the child's schema, but should include familiar concepts. Cognitive conflict introduces the challenge of the activity, which leads to social construction. Here, students think through the problem in partners or small groups with probing questions from the teacher. Metacognition refers to the reflection of the activity, while bridging encourages transfer of the knowledge to different situation and subjects. The biggest challenges include changes that both teachers and children need to make in order to be receptive to these activities (Serret, 2004).

Multiple facets must be in place in order for the constructivist curriculum to truly succeed. There can be gaps in implementation, including the willingness of teachers to recognize need for change and realize that the way students are presented with information should be considered. When participating in inquiry based teaching and hands on learning, teachers may feel a loss of control by letting students explore, hypothesize, and have small group discussions to share conjectures. For teachers who are less experienced in teaching the sciences, these fears can override, and more traditional teaching methods may be used instead (Devlin-Scherer & Zinicola, 2003). Support must be provided with any sort of curriculum change in order to engage
all levels of staff, teachers and administrators, in order to ensure they have a correct understanding of the terms, application, and need for curriculum reform (Cooper, 2007).

In regards to the Next Generation Science Standards as previously discussed, the one of the weak links in implementing these standards may be instructional material. In order to support the type of curriculum that is put forward by these new standards, many instructional materials need to be developed or modified. This creates a challenge for not only teachers, but administrators as well. Resources for implementation of these standards may not be available to all schools everywhere and the execution of such a curriculum may require additional teacher training and awareness. Many teachers and administrators may not fully understand the implementation of such a constructivist based curriculum (Bybee, 2013 and Cooper, 2007).

**Student Attitude Regarding Inquiry-Based Learning**

**Student engagement in science.** Students view their education in a number of different ways. All students come into the classroom with background knowledge about the natural world that is relevant to their lives in some way. When it comes to learning science, relevance to student lives is key. In order to change one’s thinking, importance of the knowledge must be clear to the learner and how that knowledge will impact the learner’s life. The learner must be aware that their current explanation of events is not sufficient, have new information that is credible and is applicable to their lives in a meaningful way (Gertzog, Hewson, Posner & Strike, 1981).

The traditional methods of science teaching tend to produce negative attitudes in students towards science learning. In these types of classroom settings, it has been concluded that students find science less interesting because the subject matter is not relevant in their present or future.
In previous studies, students have also stated that their interest in science wanes due to the fact that there is less time for exploration of the topics through either discussion or hands-on activity (Gibson, 1998). When students are not actively engaged in the design of experiments and activities, they are less likely to feel ownership of their learning. The activities to be carried out are viewed as a set of directions, given by the teacher to the students (Gautreau & Binns, 2012).

**Positive attitude impacts.** Short term studies have shown that students taught with inquiry-based lessons have a more positive attitude toward science and science learning, while those taught with more traditional, didactic methods did not. Students have also been found to score higher on post-tests than those taught with lecture and traditional methods after experiencing inquiry-based lessons (Chang & Mao, 1998 and Selim & Shrigley, 1983). Long term impacts of inquiry-based science teaching have been found to be positive and encourage student involvement and interest in a science career (Gibson, 1998 and Gibson & Chase, 2000).

Student attitude has also been linked to achievement in science. One of the influences found to play a role in student attitude is the way in which science is taught. Involving students in the process of their learning will encourage not only the content to be retained. Active participation also enlightens students as to their own preferred method(s) of learning. For students who have difficulties learning in a more traditional classroom setting, hands-on, inquiry-based learning may be beneficial. Students involved in inquiry science will also benefit in the long term. Although some students may be able to use rote memory for short term achievement, such as test grades, their true understanding of the topic will be limited. The experience of conceptual difficulty in the science classroom can be related to their attitude towards themselves and their ability to learn. In other words, students who have been found to have a low opinion of
themselves, the subject, or their learning will be more likely to experience difficulty in the classroom (Ferrer, 1990 and Freedman, 1997).

The importance of a positive attitude towards science and science learning cannot be overstated. Not only is there a direct link between achievement in science and student attitude, but there are many social issues that are directly rooted in science. Climate change, food security, genetics, and engineering are all issues that the students of today will need to deal with in the future. In order for the students of today to effectively participate in society regarding these issues, they should have a positive attitude towards science that will help them become educated, gain experience, and possibly a career in science related fields (Selim & Shrigley, 1983).

Conclusion

In light of the fact that since elementary science education has been scaled back in recent years, a great many students are lacking in the basic foundational skills required for critical thinking and scientific problem solving. This puts students at a disadvantage when they enter middle school and are faced with science as a separate subject, something many students have had little experience in. Constructivist methods have long been held to be effective in the teaching of science. Many have recognized that the need for students to have critical thinking skills that are built and supported from an early age. The New Generation Science Standards and Common Core Curriculum are an answer to this plea, asking educators to begin building basic skills early in a student's education, which can be added to as the child moves through to high school and beyond. Implementation of this type of curriculum certainly faces some challenges, but may be effectual in building the foundation of knowledge, scientific inquiry, and critical thinking skills that many students lack.
Summary

Within this review of the literature, I have included studies that are key to my research questions. The research shows that inquiry-based teaching and constructivist methods, when applied to science teaching, are beneficial for students. With the mandate of NCLB, science education has been put aside by many elementary schools and teachers, putting students at a disadvantage when it comes to critical thinking, inquiry, and their attitude towards science. Inquiry-based science teaching has been shown to have a positive impact on student attitude towards science and science learning as well as student ability to build critical thinking and inquiry skills. In the next section, I will present an overview of the methods which will be used in order to collect and analyze data for this research.
CHAPTER 3

Methodology

Introduction

In this section, I will introduce the methods that were used in order to collect and analyze data in relation to the research questions proposed:

1. What will be the impact of changing my science teaching from a didactic to a constructivist-based model on my development as a teacher?

2. Will the science lab report scores of my 7th grade students taught using inquiry-based methods be higher than scores of students taught using traditional didactic methods?

3. Does implementing inquiry based lessons give middle school science students a more positive attitude toward science?

Research Methodology

Overall research design and specific research plan

In order to answer the research questions stated above, an action research plan was used. Greenwood, Whyte, and Harkavy (1993) deem action research to be a process in which the researcher is a collaborator and member of the group while working with other members in order to transform those organizations. This method is beneficial for developing and creating an action plan to be implemented in my classroom, while perpetuating the Think, Act, Evaluate cycle so important to teaching practices. Additionally, in a classroom setting where a teacher is not able
to withdraw from being a member of the group, and cannot be an outsider merely observing, this method is best. Both the participants (my students) and the researcher (myself) are working together on various levels in order to answer the research questions proposed.

The specific method of classroom action research used was practical action research, which is designed to address a particular problem in the community of my classroom. Participatory action research heightens problem and hypothesis formation, acquisition and analysis of data, synthesis, and application of new ideas (Greenwood, Whyte, & Harkavy, 1993). Practical classroom action research is beneficial for teachers because it is an accurate, methodological way in which teachers can study their own practices and implement research-based methods in order to modify their teaching. Action research, with the teacher acting as researcher and participant, allows data to be collected from all sides of the issue marked for intervention.

As with action research in general, both qualitative and quantitative methods were used in this study. Unlike traditional action research, this study compared two groups of students: an experimental group, and a control group. That is, the study was conducted with two of my classes but the intervention was implemented in only one class; the other class served as a control for comparison. The intervention included the use of inquiry-based laboratory activities for students in the experimental class, whereas the control group was taught the same subject matter but using traditional didactic methods. Therefore, the independent variable was the shift from a didactic to inquiry-based laboratory activities and the dependent variables consisted of student attitude towards science learning student science achievement. The quantitative nature of this design notwithstanding, it is still a part of my action research and therefore data analyses was performed according to guidelines for action research.
Setting

The setting of this research project was “Atreides Middle School,” located in central California. Information provided consists of census data, publicly available on the Internet via school and city websites.

Community. “Sudden Valley” is a city consisting of 154,484 residents, 100% of whom are residing in an urban area. The median resident age for this city is 28.8 years. The number of residents per household is above the average for California, at 3.7 people. The demographics of Sudden Valley are as follows: 75.5% Hispanic, 15.7% White alone, 5.9% Asian alone, 1.2% Two or more races, 0.9% Black alone, 0.4% American Indian alone, .2% Native Hawaiian and Other Pacific Islander alone, and 0.1% Other race alone. In this particular city, 32.3% of residents were born in Latin America. The estimated household median income in 2011 was $44,387. Poverty rate is 22.0% city-wide, slightly higher for Latino or Hispanic residents (26.7%) and Other race residents (29.9%). Sudden Valley produces 30% of the world’s lettuce and is often cited as the “Salad Bowl of the World.” Situated in between two sets of mountains surrounding the city to the east and west, “Sudden Valley” is 52 feet above sea level, with the western part of the valley open to the coastline (www.city-data.com).

School. The research conducted took place at “Atreides Middle School,” one of the two schools in the district. The current enrollment for this school is 306 students in grades 6, 7, and 8. Student demographics do not follow the trend for the city, with 58% of the school population listed as White, 32% Hispanic/Latino, 5% Asian, 4% Filipino, and 1% African American. The number of students who qualify for free or reduced lunch is 61 (17%). In regards to language, 3% of students here are English Language Learners This particular middle school has a
Student/Teacher ratio of 25:1 and employs 14 full time teachers (www.publicschoolsk12.com). The majority of teachers are female, with just one male teacher.

**Class.** This research was done in two 7th grade Life Science classroom consisting of 57 students total. In Class A’s population, 14 students are female and 14 are male. Class B has 14 females and 15 males.

**Research Participants**

**Students (entire class).** The action research was conducted using the entire class except those students opting out of participation. Part of the reasoning surrounding the use of the entire classroom stems from the fact that as an action researcher, the teacher will be an active participant in the process. Therefore, it is out of convenience that I used two periods of my Life Science classes. Class A served as the control group. Class B as the experimental group. These particular classes were chosen due to their similarity and current grades. Class A was maintaining a current average of 86.5% while Class B was carrying an average of 85.6%. The students participating in the study numbers 40 students, enrolled in these two periods. The age range in both classes is 11 to 13.

**Teachers.** This study will involve me as the only teacher participating in the action research. I am a 30 year old, white female, recently married with no children. I hold a Bachelor of Science in Biology with a focus on marine biology and a preliminary Single Subject teaching credential in the area of Biological Science. During the school year of 2011-2012, I participated in a credential program while co-teaching 7th grade Life Science at a nearby middle school. This school year marks my second year teaching in my own classroom at Atreides Middle School and
the second year of my participation in the Induction (formerly Beginning Teacher Support and Assessment) program. Prior to my transition into classroom teaching, I taught outdoor education in the field of marine and environmental science. Five of these years were spent on Catalina Island, where I encouraged students ranging from middle school to high school to explore the environment and marine ecosystem through hiking, snorkeling, kayaking, and various hands-on laboratory activities. Before I lived in California, I taught river and salmon ecology to middle school students on the banks of the Santiam and Mackenzie rivers in Oregon, my home state.

Data collection

Quantitative Data. A survey designed to elicit student attitude towards science class and science lessons was given prior to the implementation of the inquiry based lessons. The questionnaire chosen for the students was used by Germann (1988) and has a Cronbach alpha of 0.94. The students responded on a 5 point Likert scale of agreement (Strongly agree, Agree, Neither agree nor disagree, Disagree, or Strongly Disagree) in response to 14 closed ended questions. This survey is included in Appendix A.

In order to address the question regarding student attitude, the survey was needed at the beginning of the research, before implementation of the inquiry-based lessons, in order to address student's current interest and attitude towards science. Both students from the control and experimental group received the questionnaire. The same survey was given after the implementation of the inquiry-based lessons. There were four lessons of this nature. The survey was then administered after the last inquiry-based laboratory activity in order to assess student's
current interest and attitude. The responses from both surveys were recorded and compared in order to detect if any changes in student attitude have occurred.

Analytic memos were used to determine which main themes were occurring throughout the reflective teaching journal kept by me during all lab activities. Analytical memos are often used as a short analysis of the main ideas, patterns, or themes emerging during research.

Artifact analysis was done on my lesson plans by an outside professional in the field of science education, Dr. Mark O'Shea. This step is included not only to ensure validity of the experiment, but also to gather data on my teaching methods. Dr. O'Shea is a professor at California State University at Monterey Bay and Program Coordinator of the Single Subject Teaching Credential Program. In order to assess my lesson plans, Dr. O'Shea used the Science Learning Cycle Lesson Plan Rubric (Bland, Dantzler, Goldston, & Sundberg, 2010) to determine if the lesson plans enacted in the classroom fit the criteria of the science learning cycle and therefore, constitute inquiry based teaching methods.

Artifact analysis was also done on student work. The analyzed work included the laboratory sheets that students turn in at the end of their activities. These were evaluated using a rubric designed by myself, including a table of specifications in order to identify the elements of critical thinking and scientific inquiry skills. In designing this rubric, Bloom's Taxonomy was used in order to identify elements of critical thinking and inquiry skill and applied to science inquiry. Each component of the rubric was aligned to a level of Bloom’s Taxonomy in order to determine if students were using higher order, critical thinking and inquiry. Data from both the control and experimental groups were compared.
Descriptive narratives were also used to gather data during this project. A running log of the preparation and implementation of each activity was kept by me, as well as notes regarding student behavior, including their engagement and reactions. This reflected obstacles I encountered while preparing for, during, or after the activities as well as notes about what may have worked well while preparing, during, or after the activities.

All data collection was done by me, the researcher and science teacher.

**Instruments.** The other instruments in this research consisted of three inquiry-based laboratory activities, all used during the Evolution unit taught by me. This signified a change from traditional didactic teaching methods to methods that are based in constructivist theory and inquiry. Specifically, these laboratory activities were done throughout a three week period in my 7th grade Life Science classroom, averaging one inquiry-based lesson per week. Due to school schedules, time for laboratory activities was limited and lessons adjusted. These lessons took place over the course of a number of school days. Class times vary between 43 minutes on Monday and Friday, 53 minutes on Tuesday and Thursday, and 32 minutes on Wednesdays.

These inquiry-based activities challenged my students to develop and use their critical thinking skills as they apply their knowledge of science concepts to laboratory situations. Students worked in small groups in order to develop hypotheses and design and carry out experiments, as well as to analyze and reflect upon the data generated from the experiment.

The reasoning behind the implementation of these inquiry-based activities stems from the fact that my students often exhibit a lack of critical thinking and inquiry skills. Many of these students were born in the first three years of the new millennium, shortly after No Child Left
Behind (NCLB), a federally mandated program, was implemented. NCLB focused on the outcomes of high-stakes testing in the areas of math and reading, with consequences for schools who failed to meet the minimum requirements. Due to these subjects being the primary focus for school, less time has been spent teaching science in the elementary classroom (Milner, Sondergeld, Demir, Johnson, & Czerniak, 2011).

While focus shifted with NCLB, so did the method of teaching. The prescriptive method of teaching favored by NCLB is not aligned with the constructivist-based curriculum, the preferred method of science teaching (Drake & Huglin, 2011). The students who are currently in my classroom have gone through their elementary school years in this type of environment. As a result, they have less experience with science inquiry and critical thinking.

**Implementation.** The participants for the study were chosen due to convenience, student grades, and variety of abilities in the class. As stated, one control group and one experimental group were used in this study. Although the two classes are similar in grade averages and student numbers, they are different in behavior. In order to carry out these experiments, Class B was used as the experimental group due to their overall ability to follow directions and behave. Class A was used as the control group.

Before the intervention in the third trimester, I developed each inquiry-based laboratory activities. For each of the three labs, I changed the student lab report format what has traditionally been used in my classroom to incorporate and elicit critical thinking and inquiry based on Bloom’s taxonomy and California State Science standards, specifically the Investigation and Experimentation (I & E) standards.
Previous to the Evolution unit of study, both classes were given a questionnaire designed to determine their current attitude towards science.

I developed three inquiry-based labs in which the experimental group participated. These were involved in the Evolution unit of study. They include the Natural Selection lab, A Day at the Races lab, Adaptation “Build a Beast” lab, and Battle of the Beaks lab. The comparison group students also will be studying the same evolution topics but conducted lab activities using traditional didactic methods. The lab report format for these students differed from that of the inquiry based labs. Elements are included in the inquiry lab to conform to the science learning cycle, while the more traditional didactic labs do not have these elements.

After each laboratory activity conducted in the classroom, data was collected from the lab reports of students in both classes by reviewing their work with a rubric that is specific to Bloom's taxonomy, critical thinking shown by the student, and the CA State Science I & E standards. This occurred approximately three times during this unit.

As the series of lessons progressed, I kept a reflective teaching log, recording the events leading up to, during, and after implementation of the inquiry-based lessons.

At the end of the Evolution unit of study, both classes were again given the same questionnaire as at the beginning of the unit to determine their current feelings towards science.

Data Analysis

As traditional for action research (Hendricks, 2006; McMillan & Schumacher, 2010), the data generated by the closed-ended questions on the questionnaire was recorded and analyzed using frequency tables and bar graphs. Student answers from the initial questionnaire were
compared with the answers from the final questionnaire to determine if any change occurred in students' attitude towards science from the beginning to the end of the unit. In addition, data from both the experimental and control group was compared using frequency tables and bar graphs to determine whether there were any differences in either science attitude or achievement between the two groups.

Analytic memos were used in order to take a snapshot of students and teacher after each laboratory activity. These memos were created after analysis of each section in the reflective teaching journal, one for each lab activity conducted in the classroom for both Class A and Class B. The memos contain information pertinent to student engagement, understanding, and observations of teacher focus, attitude, and control. These three themes have been identified in each section of the reflective teaching journal and discussed in each analytical memo.

Teacher lesson plans were analyzed using the previously mentioned Science Lesson Cycle Lesson Plan Rubric. Scoring on this rubric ranges from zero to four, or Unacceptable to Excellent. This data is displayed in table and bar graph for each lesson plan evaluated. Each lesson plan and corresponding scores are shown on a table outlining the four areas analyzed. These areas include Necessary Elements (materials, standards alignment, clear objectives), Exploration, Invention, and Expansion. Within each category, there are 1 to 5 areas in which the lessons were evaluated. Data for each lesson plan was compiled into a table, which was then recorded as a bar graph in order to compare each lesson plan in each area analyzed.

Student work from both classes was analyzed using the previously described rubric specific to critical thinking skills. Scoring of student artifacts occurred on the rubric scale of one to four. Within the experimental class, the initial inquiry-based laboratory activity was compared with
the second, third, and fourth activities to determine if a change occurred in regards to students' critical thinking and inquiry skills. This information is presented in the form of tables and bar graphs. In addition, student rubric scores on the final labs has been compiled into a table and then bar graph in order to compare science achievement between classes. This data has been examined in order to determine if a change has taken place.

**Limitations and Threats to Internal Validity**

Efforts have been undertaken in order to strengthen the internal validity of this research, as threats to overall validity exist and must be taken into account as limitations of usefulness of the findings.

As a teacher and action researcher, I have not been formally trained in the development and implementation of an inquiry-based constructivist curriculum or methods in which to enhance critical thinking skills. Due to these facts, it may be that I omitted or changed key features of this curriculum that may affect the success of the intervention. In order to combat this and enhance validity, my lesson plans have been checked by Dr. Mark O'Shea, a professional who has no stake in the outcome of this research.

As the study progressed, my interpretations may have been open to unconscious bias. Bias could have occurred during the collection, analysis, and interpretation of data as well as influenced student responses. As such, it was imperative for me to adhere to previously planned protocol in order to minimize this threat.
As the study is consists of more than one laboratory activity, students may have begun to discuss with one another the different activities in each class. An effort was made to isolate the groups from one another, but some diffusion may have occurred.

In this study, the participants were not selected at random. Participants were sorted into separate classes at the beginning of the school year. An overview of the Life Science 7th grade classes taught by me this year showed that the two class picked were similar in their gender distribution, age, and ethnicity. The students, however, varied in their individual achievement ability. The average grade of each class is not the same, with some classes having a higher number of high achieving students and others with a high number of lower achieving students. These factors may have influenced the results of this research.

Summary

Within this section, the methodology used in conducting my research has been explained. Data collection tools gathered both qualitative and quantitative data. All quantitative data was analyzed and triangulated in order to answer the research questions proposed. Qualitative data was reviewed in order to determine themes that may have occurred. The next section will review the data collected and results of the intervention.
CHAPTER 4

Results

Introduction

In this section, the qualitative and quantitative data collected will be analyzed and discussed. The results gathered endeavored to answer the research questions below.

1. What will be the impact of changing my science teaching from a didactic to a constructivist-based model on my development as a teacher?

2. Will the science lab report scores of my 7th grade students taught using inquiry-based methods be higher than scores of students taught using traditional didactic methods?

3. Does implementing inquiry based lessons give middle school science students a more positive attitude toward science?

Two classes of 7th grade science students, Class A and Class B, were used during this study. Class A contained 19 student subjects and represented the control group. Class A was given laboratory activities in which more traditional, didactic teaching methods were used. Class B also contained 19 student subjects, was used as the experimental group, with students participating in inquiry based lab activities. Both groups were given the same goals for each lab activity and scored on the same rubric. The rubric for each lab was specifically designed to correlate to different levels of Bloom’s Taxonomy and gauge the levels of critical thinking present in student work.

Qualitative Data Sources and Discussion
Reflective teaching journal and analytical memos

Throughout the duration of this research project, a reflective teaching journal was kept in order to record observations and descriptions of my experiences in preparation for and during the lab activities given to students. Analytical memos were written after each lab activity upon review of the reflective teaching journal in order to determine the impact and change to teaching methods from didactic to inquiry based activities. Within each analytical memo, three major themes from the reflective teaching journal were identified: student engagement, student understanding, as well as teacher attitude, focus, and control. All analytical memos are included in Appendix A.

Student engagement. Students in Class A were observed to be less engaged during each activity than students in Class B. Previous to each lab activity, students in Class A were instructed to record the central question and other pertinent information needed for the lab activity. During this preview of the lab, students often had blank looks, volunteered few comments, and appeared generally disengaged. In contrast, throughout the experiment phase of each activity, Class A students were very engaged, actively participating in the experiment. Each lab had a form of competition to simulate organisms competing for resources or survival in order to simulate natural selection. Most students very much enjoyed competing with one another. However, during their analysis of the lab after the experiment activity, students in Class A were consistently off task. Few students continued to work as a group during the analysis, and many students wrote what appeared to be a minimum for each analysis question.

Class B also participated in previews of each lab activity. There was little discussion and input from students during this time, but they were generally excited to work in groups to design
an experiment. More group work was observed during the labs done by Class B, as students were engaged during the majority of the creation, execution, and analysis of their experiments. A level of collaboration was seen in Class B that was not observed in Class A, including working as a group during the analysis and discussion of their experimental results.

**Student understanding.** This particular theme cropped up in the second and third analytic memo from analysis of the reflective teaching journal. During the first lab, A Day at the Races, Class A seemed to demonstrate a deeper understanding between the experiment done and the larger theme of natural selection and evolution. Class B had a difficult time during the second lab activity, the Natural Selection Lab, drawing connections between the experiment and underlying concept embedded in the laboratory activity. Students in both Class A and Class B had trouble identifying the variables present in the experiments during the first and second lab activity. Class A demonstrated a basic understanding of natural selection throughout all labs. Class B however, drastically improved their skill in being able to recognize, identify, and discuss the variables as they progressed to the third inquiry lesson, the Battle of the Beaks Lab. This group also improved in their experiment design and connection between their experiment and natural selection as a process in nature.

Class B, the inquiry focused group, designed their experiments and formulated their own hypotheses. Class A did not design the experiments they conducted and came up with their own hypothesis for just one lab activity, the Natural Selection Lab. The majority of groups in Class B came up with experiments that did not test their hypothesis or were not true experiments during the same lab activity, the Natural Selection Lab. However, during the Battle of the Beaks Lab, Class B improved, with the majority of groups designing relevant, true experiments to test their hypotheses.
Teacher attitude, focus, and control. Throughout all lab activities, certain themes continued to be seen in both the reflective teaching journal and analytic memos. Teacher attitude towards the different classes and methods of teaching was seen. The word “irritation” in its various forms appears often in the reflective teaching journal, typically in reference to Class A. This attitude appears to stem from students wasting time during class, their minimal engagement, and appearing to contribute the minimum required for the project. However, the same feeling was expressed in regards to the first experiments and understanding demonstrated by some groups in Class B as they created experiments for the Natural Selection Lab that were not true tests or showed great misunderstanding given the task and central concepts. Feelings of frustration towards Class B faded and were replaced with pride as students gained experience and were able to execute better experiments for the Battle of the Beaks Lab.

Teacher focus and control were also central in the reflective teaching journal. Time spent in class was seen to be a major point of focus in the classroom during all lab activities with both Class A and Class B. As seen in all three analytical memos for each lab activity, anxiety was felt over the amount of time that each activity took. Class A, taught in the more traditional, didactic method, was easily sped along by teacher direction and finished activities at a much quicker pace than Class B. Class A completed the first lab, A Day at the Races, in three class periods whereas Class B took four. This time period was the same for the second lab, the Natural Selection lab. However, the last lab, the Battle of the Beaks, took Class A four class periods and Class B two. The inquiry based lessons taught in Class B elicited a great amount of anxiety over time at the beginning of this research. Pressure to maximize class time caused the daily schedule to change for Class B and imposition of time limits on Class A.
Control over student progress was also observed during expression of time management issues in the reflective teaching journal and analytical memos. Class A, taught with more traditional methods, were given many parts to their lab activities. Class B, venturing with less direction using inquiry based methods needed to find these answers on their own. As seen in the analytical memos for all three labs, students did not always make the connection between the activity, experiment, results, and larger themes behind the lab activity. This lack of connection was distressing, causing anxiety to be felt due to the time each activity was taking while students investigated these conceptions. The same feelings of anxiety were felt over student inability to make the correct connections between these elements despite leading instructions, questions, or remarks during conversations with their teacher. As a result, struggles with control over student progress was felt with Class B. Class A was led in a specific direction from the beginning of each activity and these labs were associated with less stress over control of student progress and understanding.

Quantitative Data Sources and Discussion

Pre and post student attitude survey

Before and after the implementation of the laboratory activities, both groups were given a student attitude survey. This was done in order to determine if any change took place in regards to student attitude after their lab experiences. Both Class A and Class B were given the same survey. The survey chosen was used by Germann (1988), has a Cronbach alpha of 0.94 and consisted of 14 closed ended questions on a 5 point Likert scale of agreement (Strongly agree,
Agree, Neither agree nor disagree, Disagree, or Strongly Disagree). The survey is included in Appendix B.

This survey was designed to elicit student’s current attitude towards science class. Each question asked about a like or dislike of science. Out of the 14 items on the survey, four of these were statements that expressed an explicit dislike of science. These were items 2, 7, 10, and 14. All other items present on the survey were statements expressing a positive attitude towards science.

Students were given the Pre Student Attitude Survey a week and a half before the laboratory activities were introduced. This was done in order to determine their current level of enjoyment or dislike towards science class without being tainted by their knowledge of the upcoming activities. Students were given the Post Student Attitude Survey immediately upon their return from Spring Break, a week after finishing the laboratory activities.

In order to determine the attitude that students had towards the subject of science, four particular items from the Student Attitude Survey were focused on. Student responses to the items associated with a dislike of science (item numbers 2, 7, 10, and 14) on the Student Attitude Survey were totaled for Class A and Class B, as seen in Table 1. Students who responded with an answer of Strongly Agree or Agree were expressing a dislike of science. Those who responded with an answer of Disagree or Strongly Disagree were showing a liking of science. The responses for Neutral were also included. Responses to these items were totaled in order to determine if any changes regarding student attitude occurred after students had experienced the laboratory activities used in the study.

Table 1
Comparison of Class A and B Pre and Post Student Attitude Survey Student Responses

<table>
<thead>
<tr>
<th>Class</th>
<th>Strongly Agree or Agree</th>
<th>Neutral</th>
<th>Disagree or Strongly Disagree</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre</td>
<td>4</td>
<td>12</td>
<td>60</td>
</tr>
<tr>
<td>Post</td>
<td>9</td>
<td>9</td>
<td>58</td>
</tr>
<tr>
<td>Class B</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pre</td>
<td>7</td>
<td>13</td>
<td>55</td>
</tr>
<tr>
<td>Post</td>
<td>5</td>
<td>14</td>
<td>57</td>
</tr>
</tbody>
</table>

Students took the Pre Student Attitude Survey before participating in any laboratory activities associated with this study. After experiencing the specifically designed laboratory exercises, students took the Post Attitude Survey. Students in Class A, the control group, responded to the survey with a generally positive attitude toward science, as shown in Figure 1. However, after the lab activities, this attitude shifted a bit, showing a greater dislike of science in the Post Student Attitude Survey. Students responding to items specific to a dislike of science totaled 4 on the Pre Student Attitude Survey and 9 on the Post Student Attitude Survey, indicating a slight change had occurred, with more students agreeing with statements showing a dislike of science. The number of students who disagreed with the statements of dislike on the Pre Student Attitude Survey was 60, showing a liking of science, fell to 58 on the Post Student Attitude Survey, indicating more students either agreed or felt neutral regarding feelings of dislike towards science.
Students in Class B, the experimental group, showed a positive outlook towards the subject of science in the Pre Student Attitude Survey, as shown in Figure 2. However, seven students responded with items showing a dislike of science in the Agree or Strongly Agree categories. After the implementation of inquiry based science lessons, student responses on the Post Student Attitude Survey showed an increase in student attitude towards science. The number of students who Agree or Strongly Agree with a dislike of science decreased to five on the Post Student Attitude Survey, showing a more positive attitude towards science. The Pre Student Attitude Survey had only 55 students disagree with statements that indicated a dislike of science, showing that they had a more positive attitude. This number went up to 57 on the Post
Student Attitude Survey, showing an increased positive attitude towards science, showing that students either Disagreed, Strongly Disagreed, or felt Neutral about the items describing a dislike of science.

![Figure 2. Class B Pre and Post Student Attitude Survey Responses](image)

**Figure 2.** Analyzing the responses from students regarding items 2, 7, 10, and 14 on the Student Attitude Survey. The Pre Student Attitude Survey shows students in class B indicating a like of science by their responses of Disagree or Strongly Disagree. The Post Student Attitude survey shows students in Class B indicating a greater like of science through the decrease in the responses of Disagree or Strongly Disagree.

**Student lab scores**

Students in Class A and B were given laboratory activities designed to deepen their knowledge and understanding about the process of natural selection and evolution through the use of experimental models and simulation. Class A was given lab activities with traditional, didactic instruction. Class B was given lab activities aligned to a constructivist model, designed
to elicit inquiry and critical thinking skills. Lab activities given to Class A and B can be found in Appendix C, while those given to Class B can be found in Appendix D. Both Class A and B were scored according to the same rubrics, which can be found included in Appendix E.

The rubrics used to score each laboratory activity were aligned to various levels of Bloom’s Taxonomy in order to measure the critical thinking and inquiry skills of students. A diagram of Bloom’s Taxonomy is included in Appendix F. Each rubric was aligned to the tasks required of students in each lab activity. Both Class A and Class B were scored on the same rubrics for each lab. For each lab activity, students were asked to complete tasks that were measured in the following categories: Scientific Concepts, Experimental Hypothesis, Experimental Design, Analysis, Conclusion, and Summary. Scores on the rubric ranged from one to four. A score of one in any category does not correlate with any level of Bloom’s Taxonomy, indicating that the task was incomplete or an inaccurate understanding of the activity has been observed in the lab report.

The category of Scientific Concepts include the first three levels of Bloom’s Taxonomy; Knowledge, Comprehension, and Application. A score of two on the rubric represented the first level of Knowledge, a score of three represented the second level of Comprehension, and a score of four represented the third level, Application. The Experimental Hypothesis category was required for all students in Class B but given to students in Class A for all but one lab activity. A score of two, three, or four incorporated the third level of Bloom’s, Application. The category of Experimental Design was only required for student in Class B, and measured the Analysis and Synthesis levels. A score of one or two does not correlate to a level in Bloom’s Taxonomy for this category. A score of three on the rubric represents the level of Analysis, and a score of four the level of Synthesis. In the Analysis category, which was required for all students for two lab
activities, a score of two on the rubric aligns with the Analysis level. A score of three or four aligns with the levels of Synthesis and Evaluation. Within the category of Conclusion, a score of two and three correlates with the Comprehension and Analysis levels, while a score of four represents the level of Evaluation, the highest level on Bloom’s Taxonomy. Within the Summary category, a score of two on the rubric correlated with the Comprehension level. A score of three represented the level of Synthesis and a score of four represented the Evaluation level.

These rubric scores were analyzed and graphed in order to determine any patterns that might be seen in the level of critical thinking demonstrated by either class during the three lab activities.

**A Day at the Races Lab.** Both classes were given the task to participate in a pre-arranged experiment in order to model the theory of evolution. Class A was given a hypothesis to test, while Class B came up with a hypothesis previous to the experiment. However, both classes participated in the experiment, data collection, and data analysis. Student work was scored according to the same rubric.

As shown in Table 2, the majority of students from both Class A and B scored on the low end of the rubric, which ranged from 1 to 4. In the category of Science Concepts, 13 students in Class A and 11 students in Class B scored a two on the rubric scale. This correlates to the level of Knowledge on Bloom’s Taxonomy, showing that most students were demonstrating a basic understanding of the underlying concepts for the lab activity. For the category of Conclusion, the majority in Class A and B again scored a two on the rubric. This shows that many students were operating in the fourth level of Bloom’s Taxonomy, the level of Analysis. The scores for the Summary category were similar for both Class A and B with most students scoring a one or two
on the rubric scale. These scores show that many students were operating within the levels of Comprehension and Application on Bloom’s Taxonomy. Graph representations of these scores can be seen in Figures 3 and 4. For each category, very few students ever scored the highest on the rubric, a four.

Table 2

*Class A and B A Day at the Races Laboratory Activity Rubric Scores*

<table>
<thead>
<tr>
<th></th>
<th>Class A</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Category</td>
<td></td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Science Concepts: Knowledge, Comprehension, Application</td>
<td>0</td>
<td>13</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>Conclusion: Analysis, Evaluation</td>
<td>7</td>
<td>9</td>
<td>3</td>
<td>0</td>
</tr>
<tr>
<td>Summary: Comprehension, Application, Synthesis, Evaluation</td>
<td>10</td>
<td>7</td>
<td>2</td>
<td>0</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Class B</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
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<tr>
<td>Category</td>
<td></td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Science Concepts: Knowledge, Comprehension, Application</td>
<td>2</td>
<td>11</td>
<td>6</td>
<td>0</td>
</tr>
<tr>
<td>Conclusion: Analysis, Evaluation</td>
<td>7</td>
<td>11</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Summary: Comprehension, Application, Synthesis, Evaluation</td>
<td>11</td>
<td>13</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

*Figure 3.* Class A Rubric Scores for A Day at the Races Lab

*Figure 3.* Class A rubric scores for the first lab, A Day at the Races. Scores indicate that most students were operating within the first four levels of Bloom’s Taxonomy, Knowledge, Comprehension, Application, and Analysis for each required section of the laboratory activity.
Natural Selection Lab. Students participated in the Natural Selection Lab in which they used paper squares to model an organism in particular environments. The experiment consisted of students placing the fictional organism, dubbed “Square Paper Fish,” against a background of either colored paper, fabric, or newspaper in order to model an environment. Class A was instructed to carry out a specific set of steps for this experiment and try particular colors of “Square Paper Fish” against specific backgrounds, or environments. Class B was given the objective, background information, and general guidelines before they set out to create their hypothesis and experiment as an inquiry based activity, with less direct instruction from the teacher.
As seen in Table 3, in the category of Science Concepts, most students from Class A scored a three on the rubric. Results from Class B contains similar scores. Both Class A and Class B were directed to come up with their own hypothesis that would be tested during the experiment. For this category, all students scored a two or above on the rubric. However, Class A had 7 students score a four, in contrast to Class B, in which only one student scored highest. All students scored a two or above in this category. In the Analysis section, all students scored a three or below. Class A shows eight students scoring a one, seven with a two, and four with a three. This differs from Class B, which has the majority of students, 13, scoring a one on the rubric. Only five students scored a two, and one scored a three in this section. For the Conclusion, Class A had six score a one and ten students score a two on the rubric. Class B was split in this category, with eight students scoring a one and two in this area. In the Summary category, students from Class A scored either a one or two on the rubric. Students in Class B were similar, split between a one and two on the rubric scale. No students in either class scored a three or above. Comparison of this data in graph form can be seen in Figures 5 and 6.

Table 3

<table>
<thead>
<tr>
<th>Class A &amp; B Natural Selection Laboratory Activity Rubric Scores</th>
</tr>
</thead>
<tbody>
<tr>
<td>Class A Category</td>
</tr>
<tr>
<td>Science Concepts: Knowledge, Comprehension, Application</td>
</tr>
<tr>
<td>Hypothesis: Application</td>
</tr>
<tr>
<td>Analysis: Analysis, Synthesis, Evaluation</td>
</tr>
<tr>
<td>Conclusion: Analysis, Evaluation</td>
</tr>
<tr>
<td>Summary: Comprehension, Application, Synthesis, Evaluation</td>
</tr>
<tr>
<td>Class B Category</td>
</tr>
<tr>
<td>Science Concepts: Knowledge, Comprehension, Application</td>
</tr>
<tr>
<td>Hypothesis: Application</td>
</tr>
<tr>
<td>Analysis: Analysis, Synthesis, Evaluation</td>
</tr>
<tr>
<td>Conclusion: Analysis, Evaluation</td>
</tr>
<tr>
<td>Summary: Comprehension, Application, Synthesis, Evaluation</td>
</tr>
</tbody>
</table>
Figure 5. Class A Rubric Score for Natural Selection Lab

![Class A Natural Selection Lab Scores](image)

Figure 5. Student rubric scores indicate that for each required component of the laboratory activity, the majority of students in Class A were operating within the first four levels of Bloom's Taxonomy: Knowledge, Comprehension, Application, and Analysis. Very few were operating using critical thinking skill, as few scores reached to the highest levels of Bloom's Taxonomy: Synthesis and Evaluation.

Figure 6. Class B Rubric Score for Natural Selection Lab

![Class B Natural Selection Lab Scores](image)

Figure 6. Student rubric scores indicate that for each required component of the laboratory activity, the majority of students in Class B were operating within the first four levels of Bloom's Taxonomy: Knowledge, Comprehension, Application, and Analysis. However, some students were able to demonstrate higher level critical thinking by scoring higher in the Analysis category, placing them in the top two levels of Bloom's Taxonomy: Synthesis and Evaluation.
The Battle of the Beaks Lab. This laboratory activity involved students competing for resources in a simulated environment. Class A had a specific set of instructions in which they tested various beak adaptations on different food sources. This class was also given a hypothesis which they were asked to investigate through their experiment. Interestingly, not all students copied the given hypothesis statement, creating different scores on the rubric. Class B created their own hypotheses in order to test beaks and food items.

Table 4 shows the scores for both Class A and B according to the rubric for this lab activity. Within the category of Science Concepts, students in Class B all scored a two or higher, with the majority scoring a three on the rubric. Students in Class A were given a hypothesis, but not all students copied it down, resulting in spread of scores between three and four. Class B, in which each group came up with their own hypothesis, showed students scoring all twos or above, with nine students earning a rubric score of four. Within the category of Analysis, all students in Class B scored on the low end of the rubric. Fourteen students scored a one on this scale. The Conclusion category was similar, with all students in Class B scoring a one or two. Summary scores were similar. Students in Class B scored either a one, two, or three in this category, although the majority (11 students) scored a two. Graphic comparison of these categories and scores can be found in Figures 7 and 8.
Table 4

Class A and B Battle of the Beaks Laboratory Activity Rubric Scores

<table>
<thead>
<tr>
<th>Category</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Science Concepts: Knowledge, Comprehension, Application</td>
<td>1</td>
<td>4</td>
<td>7</td>
<td>7</td>
</tr>
<tr>
<td>Analysis: Analysis, Synthesis, Evaluation</td>
<td>9</td>
<td>9</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Conclusion: Analysis, Evaluation</td>
<td>8</td>
<td>11</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Summary: Comprehension, Application, Synthesis, Evaluation</td>
<td>13</td>
<td>5</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Class B</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Category</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>Science Concepts: Knowledge, Comprehension, Application</td>
<td>0</td>
<td>4</td>
<td>9</td>
<td>6</td>
</tr>
<tr>
<td>Analysis: Analysis, Synthesis, Evaluation</td>
<td>14</td>
<td>5</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Conclusion: Analysis, Evaluation</td>
<td>8</td>
<td>13</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Summary: Comprehension, Application, Synthesis, Evaluation</td>
<td>6</td>
<td>11</td>
<td>2</td>
<td>0</td>
</tr>
</tbody>
</table>

Figure 7. Class A Rubric Scores for Natural Selection Lab

Figure 7. Student rubric scores indicate that the majority of students in Class A were operating in the first three levels of Bloom’s Taxonomy, which include Knowledge, Comprehension, and Application. Very few students were found to operate in the levels of Analysis or Synthesis, which indicate higher order critical thinking.
Hypothesis and Experimental Design

Due to the nature of inquiry based laboratory activities, Class B had the added challenge of creating a hypotheses and experimental designs. The first lab activity, A Day at the Races, these students were asked to come up with a hypothesis for the experiment that would be conducted. Students had already previewed the experimental procedure together as a class. They were then asked to work in small groups in order to formulate their own hypothesis, which could be the same or different from their group members. During the second and third inquiry based activities, the Natural Selection and Battle of the Beaks Lab, students in Class B were tasked with hypothesis formation and experimental design, which they worked on in small groups that were either assigned or chosen by the students.
For two of the three inquiry based labs, students in Class B were asked to design their own experiment. Scores in this area were based on the student’s experimental design as it related to their hypothesis. For this category, scores of one or two on the rubric did not correlate to a level in Bloom’s Taxonomy. A student scoring a one or two either did not complete the requirement or had a flawed understanding of the concepts expressed in the laboratory activity. A score of three on the rubric correlates to the level of Analysis and a score of four aligns with the level of Synthesis on Bloom’s Taxonomy. As seen in Figure 9, all students scored a two or above on the rubric in this category. The majority of students scored a three for their experimental design in the Natural Selection Lab, indicating that they were operating on the Analysis level of Bloom’s Taxonomy. During the Battle of the Beaks Lab, most students earned the highest score of four on the rubric, showing an increase from the previous lab. This also indicates that most students were operating on the Synthesis level, the second highest on Bloom’s Taxonomy. Also in this lab, far fewer students scored a two on the rubric, showing an increase in the level of critical thinking for this category.
As shown in Figure 10, students were asked to create a hypothesis for all three lab activities. When examining all three labs, none of the students scored a one, showing that all students were operating in the third level in Bloom’s Taxonomy, Application. As seen in the first lab, A Day at the Races, most students scored a two on the rubric. However, scores improved as students moved on to participate in the second and third labs, with students consistently scoring a two or above on the rubric scale. The final lab, the Battle of the Beaks Lab, shows that the majority of students scored a four on the rubric, which on previous labs only few students had done. Overall, these scores indicate a better understanding demonstrated by the students, as they were better able to correlate their experimental designs and hypotheses, giving them higher rubric scores.
Lesson plan analysis

Analysis of the inquiry based laboratory activities given to Class B, the inquiry group, was done by Dr. Mark O’Shea during the time research was occurring in the classroom. This analysis was included not only to ensure validity of the experiment, but also to gather data on teaching methods. Dr. O’Shea is a professor at California State University at Monterey Bay and Program Coordinator of the Single Subject Teaching Credential Program. In order to assess the laboratory activities used, Dr. O’Shea scored them according to the Science Learning Cycle Lesson Plan Rubric (Bland, Dantzler, Goldston, & Sundberg, 2010) to determine if the lesson plans enacted in the classroom fit the criteria of the science learning cycle and therefore,
constituted inquiry based teaching methods. This rubric and lab scores done by Dr. O’Shea can be found in Appendix G. Out of a possible 60 points on the rubric, the score for A Day at the Races Lab activity was a 49, Natural Selection Lab a 48, and the Battle of the Beaks Lab a 55. On all three laboratory activities, scores given were either a two, three, or four. These categories are Average, Good, and Excellent, respectively. Given the analysis, all three inquiry based labs that were conducted during this experiment meet the criteria for the science learning cycle and inquiry based teaching methods.

Summary

This section has described both the qualitative and quantitative data collected during this experiment. Teaching attitude, focus, and control were discussed, as well as student engagement and student understanding. All of these themes were found to have an effect on teaching methods. Student responses from the Pre and Post Student Attitude Survey were analyzed. Students in Class A were found to increase in their dislike for science, while those in Class B were found to increase in their liking of science. Student lab scores were also analyzed. Students who participated in the inquiry lab activities demonstrated slightly higher levels of critical thinking in certain categories than students in Class A. However, scores were similar for many categories required for each of the three lab activities, indicating similar levels of critical thinking skills aligned to Bloom’s Taxonomy.
CHAPTER 5

Discussion and Action Plan

Introduction

In this section, the results of the research will be discussed with regard to their connection to the original research question. Results will be connected to the previously discussed purpose and problem. Connections to the main ideas present in the literature will also be addressed. The Action Plan outlined in this section is focused on implementing inquiry-based teaching methods in 6th, 7th, and 8th grade classrooms at Atriedes Middle School in Sudden Valley, California, based on the success of the 7th grade students who were subject to inquiry-based teaching methods.

Summary

As previously discussed in the Statement of Purpose, Problem Statement, and Literature Review sections of this research, the main concerns driving the implementation of this project included the effects of the No Child Left Behind program and the classroom instructional shift away from a constructivist based education to scripted lessons and mandated high-stakes testing. Curriculum does not always match the cognitive development of the learner, but inquiry based lessons allow the learner to build off of previous knowledge, encouraging them to have an active role in creating knowledge and deepening understanding (Taber, 2006). Often, this gives the learner to opportunity to conduct investigations that mirror real life science (Driver & Easley, 1978).
Many students have had little experience in their elementary years building critical thinking and inquiry skills in the subject of science. It was hoped that through the implementation of this research, students would be able to build critical thinking and inquiry skills, increase their positive attitude towards science, and that important pedagogical changes could be identified. The three research questions that were addressed during this project were:

1. What will be the impact of changing my science teaching from a didactic to a constructivist-based model on my development as a teacher?

2. Will the science lab report scores of my 7th grade students taught using inquiry-based methods be higher than scores of students taught using traditional didactic methods?

3. Does implementing inquiry based lessons give middle school science students a more positive attitude toward science?

**Impact on Teaching Methods**

The first research question focused on the impact that the implementation of these lessons would have on me as a teacher. In order to set up a true inquiry based lesson which students can benefit from, the teacher must set up a situation in which the student can successfully navigate a conceptual change and that the laboratory activity will lead them to the correct conclusion. (Hodson, 1990 and Gertzog, Hewson, Posner & Strike, 1981). Teachers have many steps to go through in the creation of these lessons including resources needed, student interest, student skills needed to complete the task, and methods regarding interpretation and communication of results (Hodson & Hodson, 1998).
As seen in the previous discussion of the Reflective Teaching Journal and the analytic memos generated, implementation of the inquiry based lessons did show an impact on science teaching. In comparing the traditional, didactic teaching methods to the inquiry based teaching methods, there were similarities and differences. One similarity was the concern over time taken by students in order to complete the lesson. As with any teacher, certain material must be covered during the school year and the minutes in each class period are of great importance. However, this opinion is likely not shared by students, who were seen “off task” when they were either bored with the material or did not want to complete it for personal reasons. Class A, the traditionally taught group, were easier to get back on track. Class B, the inquiry group, needed more time in order to think through the material and do some real investigation to solve the proposed problems. This type of learning cannot be hurried along by the teacher. Although the time taken for Class B to complete their experimental designs and investigations was initially a stressor for the teacher, after some experience with this type of learning, it was easier to facilitate students instead of pushing them to complete their tasks.

Student engagement was also addressed within the analytic memos and Reflective Teaching Journal. As seen in all three memos, students in both Class A and B were engaged during the experimental phase. All three of the laboratory activities involved competition, which is exciting to students. However, many student in Class A and B had a difficult time remaining on task when it came to the interpretation of their results. Although they were encouraged to complete their analysis to the best of their ability, it is possible that they found this part of the lab, whether it be the traditionally taught or inquiry based, more difficult, cognitively demanding, and therefore less engaging. In order to facilitate critical thinking by students, leading questions were asked and teacher support was given. This student support for
engagement is similar to a regular day in the classroom, where the teacher provides conversation or situations that lead the student to an answer or concept.

As students moved through the laboratory activities, it was observed that the understanding of the different concepts was not shared by all students. This issue mostly arose with Class B, the inquiry based lab group. Class A, who was given the more traditional didactic instruction, did not design their own experiment and only came up with their own testable hypothesis one time. Teacher control over student direction became apparent here. Class A received directed instructions on the objective, hypothesis, procedure, and data collection in order to successfully complete their lab activity. Due to these detailed instructions, the same frustrations were not seen with Class A. During instruction with Class B, however, the issues surrounding student understanding and teacher control were visible. A change in pedagogy from the traditional classroom was perceived as difficult because less direction was given and students had difficulty connecting their hypothesis, experiment, and central objectives. I was not able to just give students the correct hypothesis or experimental design, which is typical for traditional lab activities. Instead, as teacher in the role of facilitator, control of progress is given to the students, with the teacher only able to lead them in the correct direction. Some students were able to successfully navigate cognitive hurdles with teacher support and questioning, others were not. Perhaps this is an indication that students were not cognitively ready to connect these ideas and objectives, their initial foundation of knowledge was not enough to support them in these activities, or their lack of previous participation in inquiry lessons has not given them the confidence or experience needed.
Student Lab Report Scores

Bloom’s Taxonomy has long been a tool for all educators in order to measure the cognitive skill of students (Forehand, 2005 and Krathwhol, 2002). Within this research, rubrics were used in order to score student lab reports. These rubrics were specifically aligned to various steps in the original version of the Taxonomy. Thus, student rubric scores gave a snapshot of their level of critical thinking. Students who were given the inquiry based lab activities were originally predicted to score higher on the rubrics, indicating higher order critical thinking.

As discussed previously, students from Class A and Class B were asked to complete the same tasks in all labs excluding the creation of experimental design and hypotheses for Class A. Interpretation of the results show that students in Class A and Class B were operating mostly within the first four levels of Bloom’s Taxonomy for all rubric categories in the first three labs. These levels include Knowledge, Comprehension, Application, and Analysis. It can be seen that in the first two lab activities, Class A scored higher in some categories than Class B, indicating higher level critical thinking. This could possible be attributed to the fact that they did not have the added task of creating an experiment, something that takes a deeper understanding and focus. Class A was given most of the information they needed in order to complete the lab, which may have facilitated their ability to score higher on the rubric and demonstrate these higher order thinking skills. In the second lab activity, scores from Class B can be seen creeping up to the higher levels on the rubric and therefore critical thinking skills. However, even after experiencing three inquiry labs, students in Class B did not demonstrate skills in the required category of Analysis that would correlate with higher order critical thinking.
As discussed previously, it was observed that students in both Class A and Class B had a more difficult time when it came to the analysis and conclusion of the data they collected in each of the three labs. It is possible that all students had trouble critically thinking about the information they had acquired and were not able to express more than a basic understanding of the underlying concepts in all rubric areas. However, Class B did improve in the Experimental Design category. Most student groups were able, in their second experimental design for the Battle of the Beaks Lab, to connect their hypothesis and experiment in a much more meaningful way, showing improvement on their rubric scores as well as jumping up the scale of critical thinking on Bloom’s Taxonomy.

**Student Attitude Towards Science**

In order to react in a positive manner towards science and science learning, students must view their activities in the classroom as relevant to their personal lives and be given enough time to actively explore the concepts and ideas at a more in-depth level, instead of being handed a set of instructions by the teacher (Gibson, 1998 and Gautreau & Binns, 2012). Students who may feel that their current scientific understanding is lacking produces a negative view of themselves and their ability to understand science and the surrounding concepts. However, inquiry based lessons can benefit students who may have had difficulties, giving them a chance to explore a concept with hands-on activity (Ferrer, 1990 and Freedman, 1997).

The research conducted did see a change in both Class A and Class B when it came to student attitude towards science and science learning. Students in Class A were found to have an increased negative opinion of science. Students in Class B, however, reported an increased
positive opinion of science. This finding directly supports the earlier assertion that students who are given a specific set of directions by the teacher do not feel ownership of their learning activity and tend to look upon this as a negative experience. In Class A, who was taught in the traditional didactic way, students were guided through each of the three lab activities in a way that may have produced this negative opinion. In contrast, Class B was asked to design experiments and come up with relevant hypotheses, giving each group and individual participant an active role and ownership over the direction and creation of major portions of their lab activity. The Student Attitude Survey results from Class B provide further support to the previous finding that students who find personal relevance, ownership, and time to explore gain a more positive view of science learning. This finding is of particular interest to me as a teacher, since inquiry based lessons are not necessarily the norm in many classrooms, although they can produce higher student engagement and give students a more positive outlook on the subject.

**Action Plan**

This research project has produced significant findings for my classroom situation and field of teaching. It has shown that students respond positively to inquiry-based learning and show an increase in their critical thinking and inquiry skills as related to Bloom's taxonomy. Due to these results, the benefits of inquiry-based laboratory activities should be discussed with the science department at our school site and a plan formulated in order to implement these activities in the 6th, 7th, and 8th grade curriculum. In light of the impending Common Core and emphasis on critical thinking skills, we need to prepare our students for the expectations that will be in
place for them when they reach high school by including inquiry-based activities in their middle school science education.

**Plan significance.** Inquiry-based lessons and laboratory activities should be implemented schoolwide at my site for many reasons. The middle school is small, and I teach 75% of the 7th grade students. I have found in my research that students exposed to inquiry-based lab activities are more positive in their attitude towards science learning and are expressing higher critical thinking skills than students who participated in labs that were not based on the Science Learning Cycle and inquiry. It would be beneficial for all students to participate in lab activities that encourage positive attitudes towards science learning and advance critical thinking and inquiry skills. I am planning to implement these lab activities in my classroom regularly throughout the school year and would like to see the rest of our science department employ this method of teaching. The other 25% of 7th graders who do not come through my classroom should have the same foundations in critical thinking and inquiry skills that their peers have had exposure to in my classroom. The same can be said for the 6th and 8th grade students, although this study focused only on 7th grade students at my site. However, the implementation of inquiry-based labs gave students a more positive outlook and a marginal boost in their critical thinking. It would be beneficial for students to continue to have exposure to these types of activities in order to strengthen and build their foundations for critical thinking and inquiry. Students could begin in 6th and continue in both 7th and 8th grade in order to prepare for their high school careers.

**Plan dissemination.** In order to demonstrate the effects of inquiry-based science teaching, it will be proposed that the three science teachers at my site be properly trained in use of the Science Learning Cycle and inquiry-based lesson planning and execution. This will be discussed at our upcoming staff meetings. My previous discussions with the other two teachers
indicate that they are ready and willing to participate. Hopefully all three science teachers will find the training beneficial and structure inquiry-based lessons into their classrooms. If they find success there, other teachers from different subjects may also be interested in integrating inquiry-based lessons into their curriculum.

**Implementation of Action Plan.** Even though there are only three of us in the science department, this is a method of teaching that may be applied to many other areas as well. First, I will be sharing my research and results in a staff meeting in order to educate the teachers at our middle school. I will give a short presentation on the development and effective teaching of inquiry based lessons.

During the next school year, there will be an opportunity for me to conduct a staff training cycle based on the results of this research and expanding to other teachers in other subject areas. This training cycle will be conducted at my school site after school for one and a quarter hours. There will be three such meetings in this learning cycle. The training will focus on the development and teaching effective inquiry based lessons, discover appropriate assessment for these lessons, and strategies for improving teacher pedagogy. Teachers will develop their inquiry lesson, observe one in action in a classroom, and report their findings to the staff at one of the regular staff meetings.

Although they will be invited to attend the above trainings, the science teachers at our school site have previously discusses implementation of more inquiries of this type. The three of us have agreed to meet and discuss how we can better serve students by incorporating inquiry based lessons into our classrooms more often. I will be sharing with them specifically the Science Learning Cycle and the requirements for a true inquiry based lesson.
Conclusion

This chapter has discussed the results of the research conducted in order to measure the impact of inquiry based teaching methods on student lab report scores, teaching methods, and student attitude towards science. It has been observed that lab report scores and subsequently the critical thinking skills exhibited by students in the inquiry based class, Class B, were higher than the scores of students in the control class, Class A. Positive student attitude towards science increased for Class B after the implementation of inquiry lessons, while an attitude decrease was seen in Class A. Finally, the impact on teaching methods including time management, control over student progress, and student engagement was seen. A plan has been proposed in order to disseminate results of this research to the middle school in question and will be put into action during the next school year.
References


http://go.galegroup.com/ps/i.do?id=GALE%7CA191011848&v=2.1&u=csumb_main&it=r&p=AONE&sw=w


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Appendix A

Analytic Memos

Analytical Memo: A Day at the Races Lab

After the implementation of this lab activity and upon review of the reflective teaching journal kept by me, a number of common threads can be seen, including teacher focus and attitude as well as student engagement.

Student engagement

Students, regardless of being in the inquiry or control group, seemed excited to participate in the experiment. The physical activity and excitement around the lab were enough to engage students for the entirety of the experiment portion of the lab.

During the data analysis and graphing, students in Class A, the control group, seemed much less engaged than they had previously been. This was observed when data synthesis was taking place and I was asking for volunteers to give information and participate in the formation of the graph. After instruction was given and few volunteers shared their ideas, students were on their own to create their graphs. It was very quiet in the room as students were working individually. After they were done, many students stopped working and then stared into space. They did not move on to any of the interpretation questions on their own. Although we discussed some of these questions as a class, many students remained silent and stared. When they had completed the questions, again many were staring into space or fiddling with their school supplies.
Class B, the experimental group, was excited for the activity and some had trouble staying on task as they formulated their central question for the lab. During the lab activities, when the experiment was going, they were all engaged. However, much like the control group, their engagement waned as they were tasked with answering the lab analysis questions. Perhaps both of these groups found the data analysis and interpretation more difficult and were not as interested as they were in the physical activity.

**Teacher focus, control, and attitude**

The focus on time has been forefront during this first lab experiment. Time is not to be wasted in a classroom, where both teachers and students need to maximize the minutes per class period. However, as the teacher, my view is different than that of the students. In both Class A and Class B, I was concerned about the amount of time spent on and off task in each class period.

Class A completed this lab in three class periods. This was accomplished in part by me, the teacher, pushing kids to meet deadlines and complete their work. Using traditional didactic instruction, I also modeled graph and hypothesis creation, which most students just copy down, allowing me to continue teaching, moving the class along at the same pace. Class B completed this lab in five class periods. The amount of time it took to prep the students for the experiment, execute the experiment, and analyze the results was almost twice as long as the control group. The amount of time this took was surprising to me. Do I have time in the year to do multiple activities like this?
Control over the classroom and the students in it is paramount to teaching. Classroom control helps to set the stage for student expectation. However, this is not the type of control I found myself focusing on. For Class A, the control group, I gave the students their testable hypothesis and modeled the graph creation in order to show them how to do it. I showed them exactly how to label their graph and which data points to use. This resulted in most students just copying what I had written. I also found that I wanted to direct their writing as they analyzed the data. I knew that some of the answers I was seeing would not score high on the rubric and wanted to direct them, but did not. In Class B, I could see that many students were focused on what I would consider the wrong part of the experiment, and I tried to lead them with questions and suggestions towards a central question and testable hypothesis. On multiple occasions, I felt the need to direct students towards the same hypothesis that I had given Class A. Some students came up with hypotheses that were close and I helped them reword their statements into a testable hypothesis. The first day gave me great anxiety over letting the students go and create their own ideas because I perceived them as incorrect. However, in the subsequent days, this feeling was more and more relaxed as I practiced guiding students instead of telling them what to do.

The attitude that I had towards this activity also changed throughout the duration for each group of students. With Class A, I found that I needed to repeat directions and ask students more than one time to complete a task, which is irritating to me. It is also difficult for me when students are intentionally wasting time. I also found that I was irritated with students who finished their answers quickly and turned their paper in, only to stare and do nothing afterwards. I can’t help but think their answers are sub-par due to their haste. Class B garnered a bit of a negative attitude from me due to the fact that they were not picking up on the cues I was giving them as to their
focus in their lab questions and hypotheses. This was irritating to me as I reasoned that if their hypothesis and the experiment are not related, they will produce poor quality answers and come to incorrect conclusions.

Analytical Memo: Natural Selection Lab

After the implementation of this lab activity and upon review of the reflective teaching journal kept by me, a number of common threads can be seen, including teacher focus and attitude as well as student engagement.

Student engagement

For the control group, during the introduction to the lab, not much interest from the students was detected by me. As a class, we went through the introduction and instruction both before and after the lab. During these times, when students were not in their lab groups, many stared into space after copying down the relevant information.

Students in Class B, however, were engaged the entire time they were working in their groups. One student who I have not heard 5 words from all year explained to me their experiment. It was obvious that all students, including those who are usually quieter, were engaged in their activity. Equally interesting is the observation that students who were very engaged during the experiment parts of the lab were less likely to be engaged as they moved on to the analysis questions. Perhaps this is a more difficult task and students are not as willing to participate.
Student understanding

In the control group, many students seemed to be fairly solid in the connection between the lab and the process of natural selection. The same cannot be said for Class B, the inquiry class. These students had the extra task of coming up with a testable hypothesis and designing an experiment to test this. They have had little practice with this during the school year. Many set up situations that were not actually experiments or tests. The majority of groups fell into two categories: the experiment was not really an experiment or the students set up a situation to which they already knew the answer. One surprising element was the lack of transfer between groups during their experiments. Groups who were having a tough time thinking of an experiment did not pick up on ideas from other groups, even after they had participated in another group’s experiment. Many groups in Class B also did their experiment first and then went back, identified the variables and wrote a quick explanation of their experiment. I believe this was done in order to obtain the “right” answer for the experiment, which would also give the “right” answer for their variables.

Teacher focus, control, and attitude

The control group, Class A, is moving much faster than the inquiry group, Class B. This may be because there is more direction by the teacher and students copy the main ideas or examples given on the document camera. Although they are still asked to discuss the analysis questions with their lab group members, less group work was observed in Class A. Instead, many students moved through the analysis questions and graph making at their own speed, which was very quick for some students.
For Class A, I found myself reviewing the same information each day of the lab in order to get students to recognize the requirements of each analysis question in hopes of eliciting more in-depth thinking about the lab and the connection to the larger theme of natural selection. I felt that students who had finished quickly had not put in enough effort and reflection about the lab and material. I mentioned it every day in order to get students to review their work. However, those who had finished quickly did not review and turned in their papers at the first opportunity. This is irritating to me, as I believe that they have not tried their best. In contrast, I believed that students whom I observed working together on each question would have better answers than those who chose the individual route.

For Class B, we skipped the usual Bell Activity at the beginning of classes in order to make more time for the experiments. I tried to be hands off for the inquiry class, Class B, I inadvertently gave them step by step instructions at the beginning of this lab. I noticed that I wanted them to go in a step by step order, but felt much better about being “hands off.” I also found that I have more time for individual students when addressing them in small groups.

I did try to ask leading questions when working with each group to determine their level of understanding. The experiments students set up were challenging to watch as a teacher, as many showed me situations they had set up that did not actually test anything. I felt frustrated because a few groups set up experiments they already knew the answer to. I felt like all they wanted to was get the “right” answer. Equally frustrating and disappointing was the lack of connection between the hypothesis and experiment for most students. Trying to have this conversation was difficult, as most students did not see the issues I was trying to point out. Although I tried to guide them when writing their summary and analysis, all students really wanted to do was answer the question on the paper, not elaborate upon their ideas.
Analytical Memo: Battle of the Beaks Lab

After the implementation of this lab activity and upon review of the reflective teaching journal kept by me, a number of common threads can be seen, including teacher focus and attitude as well as student engagement.

Student engagement

For Class A, the control group, students were engaged during the experiment section of the lab. Before the experiment, many students appeared to be unengaged as the directions were discussed. After the experiment, quite a few students appeared to be wasting time in order to avoid doing the tougher analysis questions. Students also seemed to be wasting the class period so they would not have to do any other work. To counter this, a time limit was set for students so they produced and finished their work.

For both classes, students were allowed to pick their own lab groups. Students all picked partners or small groups that they work well with. Students in Class B were engaged throughout the entire activity, including the analysis questions. Although one group had some trouble staying on task during the analysis, most students were engaged in creating their answers. Most seemed excited and full of ideas when it came to creating the experiment and were also active participants during their analysis questions. Many students discussed each question in their group and moved through them together.

Student understanding
When students did not work together or finished work quickly, as observed in Class A, I believe that their understanding is not as deep as it should be and that they have not applied this understanding sufficiently in their work. Students in both Class A and B also appeared to have a hard time answering all parts of the analysis and making connections between the variables. However, this is the second lab in which Class B created a hypothesis, identified variables, and conducted an experiment. Given their experience, most groups were able to come up with these things in a short period of time.

Some students in Class B again designed an experiment that they already knew the answer to. They argued that this is showing “support for the theory of natural selection.” In order to obtain the correct answer, they have rigged their experiment to provide the results they want.

**Teacher focus, control, and attitude**

I noticed that although I was planning on letting Class A come up with their own hypothesis, I gave it to them during our instruction before the experiment. I had not planned on this, however, the need to direct students a certain way overtook me.

I have been able to be more comfortable with Class B and letting students work at their own pace, but many students in Class A appeared to be purposely wasting time in order to avoid work. This is incredibly irritating to me, as work has been put into setting up this lab and they are not applying themselves in the way I think they should. Time is also incredibly important in teaching, as we only have a limited amount in order to accomplish work during the school day and year. In contrast to Class A, students in Class B were so impressive during this lab. They were able to come up with the foundations for their experiment in the first 30 minutes of the
activity! The previous lab took them 3 class periods in order to get to this point. I was very proud of them and can see how this type of activity really lets students build their own understanding, as it greatly improved their skill and deepened the connection between activity and concept over just three lab activities.
Appendix B

Pre and Post Student Attitude Survey

Student Attitude Survey

Please use this scale to answer the following questions:

SA - Strongly agree
A - Agree
N - Neither agree nor disagree
D - Disagree
SD - Strongly disagree

(Circle one choice.)

1. SA  A  N  D  SD  Science is fun.
2. SA  A  N  D  SD  I do not like science and it bothers me to have to study it.
3. SA  A  N  D  SD  During science class, I am usually interested.
4. SA  A  N  D  SD  I would like to learn more about science.
5. SA  A  N  D  SD  If I knew I would never go to science class again, I would feel sad.
6. SA  A  N  D  SD  Science is interesting to me and I enjoy it.
7. SA  A  N  D  SD  Science makes me feel uncomfortable, restless, irritable, and impatient.
8. SA  A  N  D  SD  Science is fascinating and fun.
9. SA  A  N  D  SD  The feeling that I have towards science is a good feeling.
10. SA  A  N  D  SD  When I hear the word science, I have a feeling of dislike.
11. SA  A  N  D  SD  Science is a topic which I enjoy studying.
12. SA  A  N  D  SD  I feel at ease with science and I like it very much.
13. SA  A  N  D  SD  I feel a definite positive reaction to science.
14. SA  A  N  D  SD  Science is boring.

References

Appendix C

Class A Laboratory Activities

Name: 
Date: Per: 

A Day at the Races Lab

Standards addressed:
7.3b The reasoning used by Charles Darwin in reaching his conclusion that natural selection is the mechanism of evolution
7.3a Both genetic variation and environmental factors are causes of evolution and diversity of organisms

Objectives:
Students will conduct and participate in an experiment in order to model the theory of evolution in action.

Materials:
- Stopwatches
- Data sheet
- Tennis ball (1 per student)
- Clipboard
- Pencil
- Calculator
- Lab paper
- Index card

Procedure:
In order to model all of the parts within the theory of evolution, we will all participate in an experiment as a class. We are now a group of animals who must struggle to survive in our environment. Look at the diagram below in order to get a sneak preview of your new environment!

![Diagram](image)

You, the organism, are the X. Each organism will have the ultimate goal of getting their tennis ball into the container. Once this is done, they will survive and reproduce the next generation. Everyone will be timed in their attempt to get their tennis ball into the container. The faster, the better!

Before we begin, let’s come up with a hypothesis statement as a class. What do we want to know?

If ____________________________

then ____________________________
We are now ready to conduct the experiment and record data! Let's head outside to our new environment!

- We will begin with everyone trying to get their tennis ball into the container. The teacher will be keeping time. When you finish, record your time on your index card.

**Initial Round:** We will begin with everyone being timed and attempting to get their tennis ball into the container.

**Round 1:** The six people with the slowest times will begin. They are the “starting population.” The three to finish first will be the survivors, who will “reproduce” by each picking 2 offspring from the audience.

- For the three survivors, record their original times, winning times, and the average of their winning speed on the data sheet.

**Round 2:** The offspring of the survivors will now compete. Three will win and survive to reproduce again.

- Fill in their original times and the average of the winning speeds on the data sheet.

**Round 3:** Repeat steps 1 & 2 until everyone has gone. If there is an odd number, more offspring can be chosen.

**Data Analysis:** After you have conducted your experiment, begin to analyze the results. Use the graph paper to make a line graph of the average speeds in each round and then answer the questions below.

Write a short summary of the experiment and include whether or not your hypothesis was proved correct or incorrect.

__________________________________________________________________________________________________________________________________________________________

Analyze the graph and data. What is it showing?

__________________________________________________________________________________________________________________________________________________________

__________________________________________________________________________________________________________________________________________________________

__________________________________________________________________________________________________________________________________________________________

__________________________________________________________________________________________________________________________________________________________
Was your hypothesis supported by the data at all? If so, discuss how.

________________________________________________________________________________
________________________________________________________________________________
________________________________________________________________________________
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Conclusions:
What conclusions can you draw from this experiment? How is this like or unlike real evolution?

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Natural Selection Simulation Lab

Standards addressed:
7.3b The reasoning used by Charles Darwin in reaching his conclusion that natural selection is the mechanism of evolution
7.3a Both genetic variation and environmental factors are causes of evolution and diversity of organisms

Objectives:
Students will conduct an experiment to test Darwin's theory of natural selection using a population of Square Paper Fish and determine how environmental factors cause evolution to occur.

Materials:
Scientific Method sheet
Stopwatches
Data sheet
Starting population of Square Paper Fish
Environment (newspaper, colored paper, patterned fabric)

We will be using square pieces of paper to represent an organism we will call Square Paper Fish. Your group will begin with a starting population of Square Paper Fish of varying colors (red, blue, white, and black). Square Paper Fish live in an environment that will be simulated by your lab group using either newspaper, colored paper (red, blue, white, black), or patterned fabric.

Procedure:

What is the central question we will try to answer by doing our experiment?

What do you already know about natural selection?


Put your previous question into a hypothesis statement.
If ___________________________________________________________
then __________________________________________________________
Conduct an experiment by observing the interaction between the environment and the Square Paper Fish. The environment will be your ____________________ variable, the one you will change.
The population of Square Paper Fish will be your ____________________ variable, the one you will observe.

Experiment procedure:
In order to see a change in the population, a predator is needed. Pick one group member to be the predator. The predator will close their eyes as another group member lays out the Square Paper Fish on the environment. When the predator hears the word “go” they will open their eyes and pick up as many squares as possible in 10 seconds. Count the number collected and record it on the data table below.
Take turns being the timer, predatory, or laying out the prey. Conduct three trials.

<table>
<thead>
<tr>
<th>Color of prey</th>
<th>White Environment</th>
<th>Blue Environment</th>
<th>Red Environment</th>
<th>Newspaper Environment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Red</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Black</td>
<td></td>
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<tr>
<td>Blue</td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>White</td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>

Create a bar graph on a separate sheet of paper to illustrate the data you have collected. **Staple this paper to your lab.**
After you have conducted your experiment, begin to analyze the results.

Provide a summary of your experiment below including what happened when you changed the variable in your experiment and whether or not your hypothesis was proved correct or incorrect.

Conclusions:
Do your experiment and results connect with any real life situations and to Darwin’s theory of natural selection?
Battle of the Beaks

Standards addressed:
7.3b The reasoning used by Charles Darwin in reaching his conclusion that natural selection is the mechanism of evolution
7.3a Both genetic variation and environmental factors are causes of evolution and diversity of organisms

Objective:
Students will design an experiment to test Darwin’s theory of natural selection by using a variety of bird beaks and food items.

Materials:
- pair of chopsticks
- plastic spoon
- pair of tweezers
- binder clips
- plastic forks
- large paper clips
- large rubber bands
- stirring sticks
- pieces of macaroni
- plastic cups
- data sheet
- graph paper

Procedure:
In the middle of the Pacific Ocean is Piggy Island, home of the Angry Birds. To determine if Charles Darwin’s observations were correct about natural selection and the theory of evolution, we will design an experiment to discover if environmental pressures will affect the population of birds.

There are a variety of birds, each with a different type of beak. The beaks are represented by either a binder clip, chopstick, tweezers, spoons, or forks. The food available to the birds includes Paper Clip Crunchies, Macaroni Munchies, Rubber Band Worms, Stir Stick Bugs.

1. As a class, let’s think about the central question that we can ask about the birds, the beaks, and the island they live on. What do we want to know in connection with Darwin’s theory of natural selection?
2. Let’s make a hypothesis to test out the theory of natural selection. We will be using an experiment involving the different birds and food supply on the island.

If ___________________________________________ then __________________________________________________________________________

3. Follow the procedure below in order to test the hypothesis.

- The ____________________ variable is the type of food you will try to eat.
  (This is the factor that will be changed.)
- The ____________________ variable is the beak structure.
  (This is the factor that will be observed)

Record who will be representing each bird type in your lab group.

  Chopstick Beak: ________________________ (Task Master)
  Spoon Beak: ___________________________ (Group Recorder – data table)
  Tweezer Beak: _________________________ (Drops food into “feeding zone”)
  Binder Clip Beak: ____________________ (Materials person)

Record your results on the data sheet attached.

1. You are now very hungry little birds. You can only eat with the tool (beak) you have selected and you may only use that tool for eating. The cup represents your stomach. It must remain upright at all times. You must hold your beak in one hand and your stomach in the other. You can only place food in your stomachs with your beak.

2. Certain food items will be placed in the feeding area (the middle of the circle). When the timekeeper says “Go” you are to collect as much food and place it into your stomach as possible until the timekeeper says “Stop.” You will have one minute to “feed.”

3. After you hear “Stop” empty your stomachs and count the contents. Tell the group recorder your total and they will fill out the Recording Sheet. The materials person places all food items back into the properly labeled baggie in your group’s basket.

4. We will repeat steps 3 and 4, using each of the other food items (stir stick bugs, rubber band worms, macaroni munchies).
After you have conducted your experiment, begin to analyze the results. Provide a summary of your experiment below including what happened when you changed the variable in your experiment and whether or not your hypothesis was proved correct or incorrect.

What would happen if all the bird types flew to an island where no birds had been before, where the only food available is macaroni munches?

Conclusions:
How do inherited structures, like bird beaks, provide adaptive advantage in a competitive environment? Does this connect to Darwin’s theory of natural selection?
### Group Data Sheet

<table>
<thead>
<tr>
<th></th>
<th>Paper Clip Crunchies</th>
<th>Macaroni Munchies</th>
<th>Rubber Band Worms</th>
<th>Stir Stick Bugs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chopstick Beak</td>
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<tr>
<td>Spoon Beak</td>
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<tr>
<td>Tweezer Beak</td>
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<tr>
<td>Binder Clip Beak</td>
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</tbody>
</table>

We will share data together as a class. Record the final numbers on the table below.

### Class Data Recording Sheet

<table>
<thead>
<tr>
<th></th>
<th>Paper Clip Crunchies</th>
<th>Macaroni Munchies</th>
<th>Rubber Band Worms</th>
<th>Stir Stick Bugs</th>
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</thead>
<tbody>
<tr>
<td>Chopstick Beak</td>
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<td>Spoon Beak</td>
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<tr>
<td>Tweezer Beak</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Binder Clip Beak</td>
<td></td>
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</tbody>
</table>

After looking at the class data, do the class results show that these repeated experiments support or do not support Darwin’s theory?

________________________________________________________________________
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Appendix D

Class B Laboratory Activities

A Day at the Races Lab

Standards addressed:
7.3b The reasoning used by Charles Darwin in reaching his conclusion that natural selection is the mechanism of evolution
7.3a Both genetic variation and environmental factors are causes of evolution and diversity of organisms

Objectives:
Students will conduct and participate in an experiment in order to model the theory of evolution in action.

Materials:
- Stopwatches
- Data sheet
- Tennis ball (1 per student)
- Clipboard
- Pencil
- Calculator
- Lab paper
- Index card

Procedure:
In order to model all of the parts within the theory of evolution, we will all participate in an experiment as a class. We are now a group of animals who must struggle to survive in our environment. Look at the diagram below in order to get a sneak preview of your new environment!

![Diagram of a circle with a tennis ball inside, marked with an X]

You, the organism, are the X. The goal is to get your tennis ball into the container in the middle without crossing the circular line as fast as possible. This will ensure your survival. Everyone will be timed in their attempt to get their tennis ball into the container. The faster, the better!

Scientific Method Step 1: Discuss with the person next to you. Knowing that the faster you can complete the task, the better, come up with a question that you might be able to answer with this experiment.
**Scientific Method Step 2:**
Create a mini-graphic organizer to connect the ideas that you have about natural selection and evolution.

**Evolution**

Use the knowledge that you already have about the theory of evolution, natural selection, and survival of the fittest in order to make a prediction about what might happen during this lab experiment.

__________________________________________________________________________
__________________________________________________________________________
__________________________________________________________________________
__________________________________________________________________________

**Scientific Method Step 3:** Put your question from **Scientific Method Step 1** into a hypothesis statement.
If ______________________________________________________________________
then ______________________________________________________________________

**Scientific Method Step 4:** We are now ready to conduct the experiment and record data! Let's head outside to our new environment!

- Each organism will have the ultimate goal of getting their tennis ball into the container. Once this is done, they will survive and reproduce the next generation. We will begin with everyone trying to get their tennis ball into the container. The teacher will be keeping time. When you finish, record your time on your index card.
**Initial Round:** We will begin with everyone being timed and attempting to get their tennis ball into the container.

**Round 1:** The six people with the slowest times will begin. They are the “starting population.” The three to finish first will be the survivors, who will “reproduce” by each picking 2 offspring from the audience.

- For the three survivors, record their original times, winning times, and the average of their winning speed on the data sheet.

**Round 2:** The offspring of the survivors will now compete. Three will win and survive to reproduce again.

- Fill in their original times and the average of the winning speeds on the data sheet.

**Round 3:** Repeat steps 1 & 2 until everyone has gone. If there is an odd number, more offspring can be chosen.

**Scientific Method Step 5 & 6:** After you have conducted your experiment, begin to analyze the results.

Use the graph paper to make a line graph of the average speeds in each round and then answer the questions below.

Write a short summary of the experiment and include whether or not your hypothesis was proved correct or incorrect.

________________________________________________________________________

________________________________________________________________________

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Analyze the graph and data. What is it showing?

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________
Was your hypothesis supported by the data at all? If so, discuss how.

__________________________________________________________________________

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Conclusions:
What conclusions can you draw from this experiment? How is this like or unlike real evolution?

__________________________________________________________________________

__________________________________________________________________________

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__________________________________________________________________________

Group Discussion:
As a class, we will discuss the results of this experiment.
Review your analysis and conclusions from the previous questions. Write down at least two ideas that you can contribute to the discussion. Use the sentence starters below to jump start your thinking.

- The results of the experiment showed that...
- This experiment models...
- The data supported/did not support my hypothesis because...
- I thought that __________ would occur, but...
- I was __________ when I observed that...

1. _________________________________________________________________________
2. _________________________________________________________________________

Be ready to contribute your comments to the class.
## Data Sheet

<table>
<thead>
<tr>
<th>Round #</th>
<th>Offspring 1 (Original Time)</th>
<th>Offspring 2 (Original Time)</th>
<th>Offspring 3 (Original Time)</th>
<th>Offspring 4 (Original Time)</th>
<th>Offspring 5 (Original Time)</th>
<th>Offspring 6 (Original Time)</th>
<th>Survivor 1 (Winning Time)</th>
<th>Survivor 2 (Winning Time)</th>
<th>Survivor 3 (Winning Time)</th>
<th>Average Times of Winners</th>
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</tbody>
</table>
Natural Selection Simulation Lab

Standards addressed:
7.3b The reasoning used by Charles Darwin in reaching his conclusion that natural selection is the mechanism of evolution
7.3a Both genetic variation and environmental factors are causes of evolution and diversity of organisms

Objectives:
Students will design an experiment to test Darwin's theory of natural selection using a population of Square Paper Fish and determine how environmental factors cause evolution to occur.

Materials:
- KWL Chart
- Scientific Method sheet
- Stopwatches
- Data sheet
- Starting population of Square Paper Fish
- Environment (newspaper, colored paper, patterned fabric)

Procedure: We will be using square pieces of paper to represent an organism we will call Square Paper Fish. Your group will begin with a starting population of Square Paper Fish of varying colors (red, blue, white, and black). Square Paper Fish live in an environment that will be simulated by your lab group using either newspaper, colored paper (red, blue, white, black), or patterned fabric.

As a class, we will discuss what we have already learned about natural selection and fill out the “What I Know” portion of the KWL chart.

In your lab group, discuss what you want to find out about natural selection and fill out the “What I Want to Know” portion of the KWL chart.

Scientific Method Step 1: What is the central question your group will try to answer?

_____________________________________________________

Scientific Method Step 2: This is the first section on your KWL chart – what you already know.

Scientific Method Step 3: Put your question into a hypothesis statement.

If ______________________________________________________

then ______________________________________________________

Now, work together in order to design an experiment that will test your hypothesis. (Remember, it is okay if your hypothesis turns out to be incorrect!)
**Scientific Method Step 4:**
Which factor will be your independent variable? (This is what you will **change** in your experiment.)

Which factor will be your dependent variable? (This is what you will **observe** in your experiment.)

Describe how you will conduct your experiment:

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________

You will need to record your observations when you conduct your experiment. Use a separate piece of paper to create a data table that you can use. Each group member will need to have their own set of data. **Staple this data sheet to your lab paper.**

Now you are ready to conduct your experiment and record your data!

**Scientific Method Step 5 & 6:** After you have conducted your experiment, begin to analyze the results.

Provide a summary of your experiment below including what happened when you changed the variable in your experiment and whether or not your hypothesis was proved correct or incorrect.

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________
Conclusions:
Do your experiment and results connect with any real life situations and to Darwin’s theory of natural selection?

Now, share and compare your results with other groups. Meet with two other groups and fill out the table below.

<table>
<thead>
<tr>
<th>Group Members</th>
<th>Hypothesis</th>
<th>Experiment Description</th>
<th>Results/Conclusion</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td></td>
<td>Independent variable:</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Dependent variable:</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Design:</td>
<td></td>
</tr>
</tbody>
</table>

| 2.            |            | Independent variable:  |                    |
|               |            | Dependent variable:    |                    |
|               |            | Design:                |                    |

For Group 1:
Was their hypothesis proven correct or incorrect? ____________________________

Do their results show a simulation of natural selection? Why or why not? ____________________________
For Group 2:
Was their hypothesis proven correct or incorrect? 

Do their results show a simulation of natural selection? Why or why not?

As an extension of this lab, go to the website: http://www.techapps.net/interactive/pepperedmoths.swf
This website is about the Peppered Moth. Click on each circle at the bottom of the page to learn about the Peppered Moth and complete the simulation.

This section covers the life cycle of the Peppered Moth.

This section describes the changing environment of the Peppered Moth.
Where are Peppered Moths found?

This section describes the experiments conducted to research the Peppered Moth.
Did Dr. Kettlewell’s experiment support Darwin’s theory of natural selection?

This section is the interactive portion where you become the predator of the Peppered Moth.
How is this simulation like the experiment you created for the Square Paper Fish?
<table>
<thead>
<tr>
<th>What I know about natural selection.</th>
<th>What I want to find out about natural selection through my experiment.</th>
<th>What I learned about natural selection from the results of my experiment.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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</table>
Battle of the Beaks

Standards addressed:
7.3b The reasoning used by Charles Darwin in reaching his conclusion that natural selection is the mechanism of evolution
7.3a Both genetic variation and environmental factors are causes of evolution and diversity of organisms

Objective:
Students will design an experiment to test Darwin's theory of natural selection by using a variety of bird beaks and food items.

Materials:
- pair of chopsticks
- plastic spoon
- pair of tweezers
- binder clips
- plastic forks
- large paper clips
- large rubber bands
- stirring sticks
- pieces of macaroni
- plastic cups
- data sheet
- graph paper

Procedure:
In the middle of the Pacific Ocean is Piggy Island, home of the Angry Birds. To determine if Charles Darwin's observations were correct about natural selection and the theory of evolution, we will design an experiment to discover if environmental pressures will affect the population of birds.

There are a variety of birds, each with a different type of beak. The beaks are represented by either a binder clip, chopstick, tweezers, spoons, or forks. The food available to the birds includes Paper Clip Crunchies, Macaroni Munchies, Rubber Band Worms, Stir Stick Bugs.

Begin to think about how you can test the theory of natural selection using the birds and their food supply.

Scientific Method Step 1: In your lab groups, think about the central question that you would like answered about the birds, the beaks, and the island they live on.
Scientific Method Step 2: What do you already know about the theory of natural selection? On a separate sheet of paper, create a concept map that connects the ideas surrounding evolution and natural selection. **Staple this paper to your lab paper. Below are some examples of a concept map.**

![Concept Map]

Scientific Method Step 3: Create a hypothesis and record it below. Use your central question to guide you, but be specific. What situation will you use in order to test the theory of natural selection?

If ________________________________ then ________________________________

Discuss in your lab group the type of experiment that will test this hypothesis using the materials available. Your hypothesis may be proven correct or incorrect by your experiment.

Scientific Method Step 4:
Which factor will be your independent variable? (This is what you will change in your experiment.)

Which factor will be your dependent variable? (This is what you will observe in your experiment.)

Describe how you will conduct your experiment:

_________________________________________________________________________

_________________________________________________________________________

_________________________________________________________________________

_________________________________________________________________________

_________________________________________________________________________

_________________________________________________________________________

_________________________________________________________________________

You will need to record your observations when you conduct your experiment. Use a separate piece of paper to create a data table that you can use. Each group member will need to have their own set of data. **Staple this data sheet to your lab paper.**
Scientific Method Step 5 & 6: After you have conducted your experiment, begin to analyze the results. Provide a summary of your experiment below including what happened when you changed the variable in your experiment and whether or not your hypothesis was proved correct or incorrect.

What would happen if all the bird types flew to an island where no birds had been before, where the only food available is macaroni munchies?

Conclusions:
How do inherited structures, like bird beaks, provide adaptive advantage in a competitive environment?
Does this connect to Darwin’s theory of natural selection?
Do your experimental results support the theory of natural selection? Why or why not?

Class Discussion and Presentation:
Work up a short presentation to share your experiment and results with the class. You will need to report your central question, hypothesis, experimental design and results.
Was your hypothesis proven correct or incorrect? Do you think that your experiment helped to support Darwin’s theory of natural selection?

As you watch other groups present, mark down whether or not the group proved their hypothesis correct or incorrect. Does their data support the theory of natural selection?

<table>
<thead>
<tr>
<th>Group Members</th>
<th>Hypothesis</th>
<th>Data</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Correct</td>
<td>Incorrect</td>
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</tbody>
</table>

After watching all of the presentations, look at the table above. Do the class results show that these repeated experiments support or do not support Darwin’s theory?
## Appendix E

### Laboratory Rubrics

#### Races Evolution Lab Analysis Rubric

<table>
<thead>
<tr>
<th>Category</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scientific Concepts</td>
<td>Report illustrates inaccurate understanding of scientific concepts underlying the lab. (Knowledge)</td>
<td>Report illustrates a limited understanding of scientific concepts underlying the lab. (Comprehension)</td>
<td>Report illustrates an accurate understanding of most scientific concepts underlying the lab. (Application)</td>
<td>Report illustrates an accurate and thorough understanding of scientific concepts underlying the lab. (Evaluation)</td>
</tr>
<tr>
<td>Experimental Hypothesis</td>
<td>No hypothesis has been stated. (N/A)</td>
<td>Hypothesized relationship between the variables and the predicted results has been stated, but appears to be based on flawed logic. (Application)</td>
<td>Hypothesized relationship between the variables and the predicted results is reasonable based on general knowledge and observations. (Application)</td>
<td>Hypothesized relationship between the variables and the predicted results is clear and reasonable based on what has been studied. (Application)</td>
</tr>
<tr>
<td>Conclusion</td>
<td>No conclusion was included in the report, OR shows little effort and reflection. (N/A)</td>
<td>Conclusion includes what was learned from the experiment. (Comprehension)</td>
<td>Conclusion includes whether the findings supported the hypothesis and what was learned from the experiment. (Analysis)</td>
<td>Conclusion includes whether the findings supported the hypothesis, possible sources of error, and what was learned from the experiment. (Evaluation)</td>
</tr>
<tr>
<td>Summary</td>
<td>No summary is written. (N/A)</td>
<td>Summary describes the information learned. (Comprehension)</td>
<td>Summary describes the information learned and a possible application to a real life situation. (Synthesis)</td>
<td>Summary describes the skills learned, the information learned and some future applications to real life situations. (Evaluation)</td>
</tr>
</tbody>
</table>

#### Natural Selection Lab Analysis Rubric

<table>
<thead>
<tr>
<th>Category</th>
<th>1</th>
<th>2</th>
<th>3</th>
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</tr>
</thead>
<tbody>
<tr>
<td>Scientific Concepts</td>
<td>Report illustrates inaccurate understanding of scientific concepts underlying the lab. (Knowledge)</td>
<td>Report illustrates a limited understanding of scientific concepts underlying the lab. (Comprehension)</td>
<td>Report illustrates an accurate understanding of most scientific concepts underlying the lab. (Application)</td>
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</tr>
<tr>
<td>Experimental Hypothesis</td>
<td>No hypothesis has been stated. (N/A)</td>
<td>Hypothesized relationship between the variables and the predicted results has been stated, but appears to be based on flawed logic. (Application)</td>
<td>Hypothesized relationship between the variables and the predicted results is reasonable based on general knowledge and observations. (Application)</td>
<td>Hypothesized relationship between the variables and the predicted results is clear and reasonable based on what has been studied. (Application)</td>
</tr>
<tr>
<td>Experimental Design</td>
<td>Experimental design is not relevant to the hypothesis. (N/A)</td>
<td>Experimental design is relevant to the hypothesis, but is not a complete test. (N/A)</td>
<td>Experimental design is adequate to test the hypothesis, but leaves some unanswered questions. (Analysis)</td>
<td>Experimental design is a well-constructed test of the stated hypothesis. (Synthesis)</td>
</tr>
<tr>
<td>Analysis</td>
<td>The relationship between the variables is not discussed. (N/A)</td>
<td>The relationship between the variables is discussed but no patterns, trends or predictions are made based on the data. (Analysis)</td>
<td>The relationship between the variables is discussed and trends/patterns are logically analyzed. (Synthesis)</td>
<td>The relationship between the variables is discussed and trends/patterns are logically analyzed. Predictions are made about what might happen if part of the lab were changed or how the experimental design could be changed. (Evaluation)</td>
</tr>
<tr>
<td>Conclusion</td>
<td>No conclusion was included in the report, OR shows little effort and reflection. (N/A)</td>
<td>Conclusion includes what was learned from the experiment. (Comprehension)</td>
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<td>Summary describes the information learned and a possible application to a real life situation. (Synthesis)</td>
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<td>Category</td>
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<td>2</td>
<td>3</td>
<td>4</td>
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<td>-------------------------------</td>
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</tr>
<tr>
<td>Scientific Concepts</td>
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<td>Experimental Hypothesis</td>
<td>No hypothesis has been stated. (N/A)</td>
<td>Hypothesized relationship between the variables and the predicted results has been stated, but appears to be based on flawed logic. (Application)</td>
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<td>Hypothesized relationship between the variables and the predicted results is clear and reasonable based on what has been studied. (Application)</td>
</tr>
<tr>
<td>Experimental Design</td>
<td>Experimental design and execution is not relevant to the hypothesis. (N/A)</td>
<td>Experimental design and execution is relevant to the hypothesis, but is not a complete test. (N/A)</td>
<td>Experimental design and execution is adequate to test the hypothesis, but leaves some unanswered questions. (Analysis)</td>
<td>Experimental design and execution is a well-constructed test of the stated hypothesis. (Synthesis)</td>
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<tr>
<td>Analysis</td>
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<td>The relationship between the variables is discussed but no patterns, trends or predictions are made based on the data. (Analysis)</td>
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</tr>
</tbody>
</table>
Appendix F

Bloom’s Taxonomy

Reference:
**Appendix G**

**Science Learning Cycle Rubric and Scores**

Data Collection Instrument 8: Lesson Plan Rubric

<table>
<thead>
<tr>
<th>0</th>
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<th>Explanation</th>
<th>Phase</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Concepts and/or skills selected for the lesson align with National Science Education Standards and relevant state/local standards.</td>
<td></td>
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</tr>
<tr>
<td>1</td>
<td></td>
<td>2</td>
<td>3</td>
<td>The lesson plan contains objectives that are clear, appropriate, measurable, and align with the assessment/evaluation.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td></td>
<td>2</td>
<td>3</td>
<td>Materials list is present and complete</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

1. **Engage and Explore**

<table>
<thead>
<tr>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>The engage of the exploration phase: Explains student interest/motivation to learn, Raises questions from children, Ellicits students' prior knowledge, Leads into the exploration.</th>
<th>Explores item 1</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td></td>
<td>2</td>
<td>3</td>
<td>During the explore phase, students are actively working on the learning task. When appropriate, teacher questions evoke the learners' ideas and/or generate new questions from students. Student inquiry may involve student questioning, manipulating objects, developing inquiry skills (as appropriate) and developing abstract ideas. *See back for list of typical inquiry skills.</td>
<td>Explores item 2</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td></td>
<td>1</td>
<td>3</td>
<td>Learning activities in the exploration phase are student centered and involve hands-on/minds-on activities.</td>
<td>Explores item 3</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td></td>
<td>2</td>
<td>3</td>
<td>The inquiry activities show evidence of student learning for formative/summative assessment. *See back for a list of formative assessment methods.</td>
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</tr>
</tbody>
</table>

2. **Invention – Phase 2**

<table>
<thead>
<tr>
<th>0</th>
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<th>3</th>
<th>4</th>
<th>Explain item 1</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>There is a logical transition from the exploration phase. There are questions (mixed divergent and convergent) for interactive discussion lead by teacher or students. Questions (regarding the activity/or data collected) lead to the development of concepts and skills. Includes a complete explanation of the concept (is, terms, and/or skill(s) taught.</td>
<td>Explain item 2</td>
</tr>
<tr>
<td></td>
<td></td>
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<td></td>
<td>The explain phase provides a variety of approaches to explain and illustrate the concept or skill. For example approaches might include but are not limited to the use of technologies: visual field trips, demonstrations, cooperative group discussions, panel discussions, interview of guest speaker, video/print/audio/computer program materials, teacher explanations.</td>
<td>Explain item 3</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>The discussions or activities allow the teacher to assess students' present understanding of the concept or skill through appropriate formative/summative assessment.</td>
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</tr>
</tbody>
</table>
**Expansion - Phase 3**

*(Elaborate and Evaluate)*

<table>
<thead>
<tr>
<th></th>
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<tbody>
<tr>
<td>1</td>
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<tr>
<td><strong>Elaborate item 1</strong></td>
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<tr>
<td>There is a logical transition from the explain phase. The elaborate learning activities provide students with the opportunity to apply and extend the newly acquired concepts and skills into new areas.</td>
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<td></td>
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<tr>
<td><strong>Elaborate item 2</strong></td>
<td></td>
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<tr>
<td>The elaborate learning activities encourage students to find real life (every day) connections with the new concepts or skills.</td>
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<tr>
<td><strong>Evaluation item 1</strong></td>
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</tr>
<tr>
<td>The lesson includes summative evaluation, which can include a variety of forms/approaches.</td>
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<tr>
<td><strong>Evaluation item 2</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>The evaluation matches the objectives. * See back for list of some methods of evaluation.</td>
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<tr>
<td>1</td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Evaluation item 3</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>The evaluation criteria are clear, appropriate, and measurable (i.e. rubrics)</td>
<td></td>
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<td></td>
</tr>
</tbody>
</table>

Point: [4/9]

### Scoring Criteria

<table>
<thead>
<tr>
<th></th>
<th>Excellent</th>
<th>Good</th>
<th>Average</th>
<th>Poor</th>
<th>Unacceptable</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>All elements are present, complete, appropriate, and accurate, with rich details. Another teacher can use the plan as written.</td>
<td>Most of the elements are present, complete, appropriate, and accurate, with rich details. Another teacher could use the plan with a few modifications.</td>
<td>Approximately half of the elements are present, complete, appropriate, and accurate, with some details. Another teacher could use the plan with modifications.</td>
<td>Few of the elements are present, complete, appropriate, and accurate, with few details. Another teacher would have to re-write the lesson in order to implement the lesson.</td>
<td>Key elements are not present. Descriptions are inappropriate. Plan lacks coherence and is unusable as written.</td>
</tr>
</tbody>
</table>

*Typical inquiry skills - predicting, hypothesizing, observing, measuring, testing, recording, graphing, creating tables, drawing conclusions*

*Typical formative assessment methods: science journals, KWL charts, concept maps, writing assignments, art work, drawings/charts, graph, quiz, test, PowerPoint presentation, 1-movie, movie, cartoons. Note that evaluation comes from the culmination of the formative assessments used during the lesson.*

*Examples of appropriate experiences are: the use of technology, Internet field trips, field trips, hands-on/minds-on learning activities, cooperative group discussions, panel discussions, interview of guest speaker, video/print/audio/computer program materials, teacher explanations, Webquest, TrackStar, 1-movie, PowerPoint*
### Data Collection Instrument #3: Lesson Plan Rubric

#### Science Learning Cycle Lesson Plan Rubric v1

<table>
<thead>
<tr>
<th>Exploration</th>
<th>Exploration</th>
<th>Exploration</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 1 2 3 4</td>
<td>0 1 2 3 4</td>
<td>0 1 2 3 4</td>
</tr>
<tr>
<td>Concepts and/or skills selected for the lesson align with National Science Education Standards and relevant state/local standards.</td>
<td>The lesson plan contains objectives that are clear, appropriate, measurable, and align with the assessment/evaluation.</td>
<td>Materials list is current and complete.</td>
</tr>
</tbody>
</table>

#### Engage and Explore

<table>
<thead>
<tr>
<th>0 1 2 3 4</th>
<th>0 1 2 3 4</th>
<th>0 1 2 3 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Exploration 1</td>
<td>Exploration 2</td>
<td>Exploration 3</td>
</tr>
</tbody>
</table>

1. The essence of the exploration phase:
   - Raises student interest/motivation to learn
   - Raises questions from students
   - Elicits students' prior knowledge
   - Leads into the exploration

2. During the exploration phase, students are actively working on the learning task. When appropriate, teacher questions evoke learners' ideas and generate new questions from students. Student inquiry may involve student questioning, manipulating objects, developing inquiry skills (as appropriate) and developing abstract ideas. *See back for list of typical inquiry skills.*

3. Learning activities in the exploration phase are student centered and involve hands-on/minds-on activities.

4. The inquiry activities show evidence of student learning for formative/authentic assessment. *See back for a list of formative assessment methods.*

#### Invention – Phase 2

(Explain)

<table>
<thead>
<tr>
<th>0 1 2 3 4</th>
<th>0 1 2 3 4</th>
<th>0 1 2 3 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Explain item 1</td>
<td>Explain item 2</td>
<td>Explain item 3</td>
</tr>
</tbody>
</table>

1. There is a logical transition from the exploration phase:
   - There are questions (mixed divergent and convergent) for interactive discussion led by teacher or students.
   - Questions (regarding the activity/or data collected) lead to the development of concepts and skills.
   - Includes a complete explanation of the concept(s), terms, and/or skill(s) taught.

2. The explain phase provides a variety of approaches to explain and illustrate the concept or skill. For example, approaches might include but are not limited to the use of technology, virtual field trips, demonstrations, cooperative group discussions, panel discussions, interview of guest speaker, video/print/audio/computer program materials, teacher explanations.

3. The discussions or activities allow the teacher to assess students' present understanding of the concept or skill through appropriate formative/authentic assessment.
## Expansion - Phase 3

**Elaborate and Evaluate**

<table>
<thead>
<tr>
<th></th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Elaborate item 1</strong></td>
<td>✔</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>The elaborate learning activities provide students with the opportunity to apply and extend the newly acquired concepts and skills into new areas.</td>
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</tbody>
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<th>1</th>
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<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Elaborate item 2</strong></td>
<td>✔</td>
<td></td>
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<td></td>
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<td>The elaborate learning activities encourage students to find real life (every day) connections with the new concepts or skills.</td>
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<th>1</th>
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<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Evaluation item 1</strong></td>
<td>✔</td>
<td>✔</td>
<td></td>
<td></td>
</tr>
<tr>
<td>The lessons include summative evaluation, which can include a variety of forms/approaches.</td>
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</tr>
</tbody>
</table>

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<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Evaluation item 2</strong></td>
<td>✔</td>
<td></td>
<td>✔</td>
<td></td>
</tr>
<tr>
<td>The evaluation matches the objectives. <em>See back for list of some methods of evaluation.</em></td>
<td></td>
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</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
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<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Evaluation item 3</strong></td>
<td>✔</td>
<td></td>
<td></td>
<td>✔</td>
</tr>
<tr>
<td>The evaluation criteria are clear, appropriate, and measurable (i.e. rubrics)</td>
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</tr>
</tbody>
</table>

### Scoring Criteria

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<th>Poor</th>
<th>Unacceptable</th>
</tr>
</thead>
<tbody>
<tr>
<td>Score</td>
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### Data Collection Instrument #3: Lesson Plan Rubric

#### Science Learning Cycle Lesson Plan Rubric v1

<table>
<thead>
<tr>
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</thead>
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<tr>
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<tr>
<td>Phase</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>(Engage and Explore)</td>
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</tr>
<tr>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
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</tr>
<tr>
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<td></td>
<td></td>
<td></td>
<td>The engage of the exploration phase:</td>
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<tr>
<td></td>
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<td></td>
<td></td>
<td>Raises student interest/motivation to learn</td>
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<td>Raises questions from children</td>
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<td>Elicits students’ prior knowledge</td>
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<td>Leads into the exploration</td>
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<td></td>
<td>Explore item 1</td>
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<td>During the explore phase, students are actively working on the learning task. When appropriate, teacher questions evoke the learners’ ideas and/or generate new questions from students. Student inquiry may involve student questioning, manipulating objects, developing inquiry skills (as appropriate) and developing abstract ideas. <em>See back for list of typical inquiry skills.</em></td>
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<td>Explore item 2</td>
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<td>Learning activities in the exploration phase are student centered and involve hands-on/minds-on activities.</td>
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<td>Explore item 3</td>
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<td>The inquiry activities show evidence of student learning for formative/authentic assessment</td>
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<td><em>See back for a list of formative assessment methods</em></td>
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<td>Invention – Phase 2</td>
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<td>There is a logical transition from the exploration phase</td>
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<td>There are questions (mixed divergent and convergent) for interactive discussion lead by teacher or students</td>
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<td>Questions (regarding the activity/or data collected) lead to the development of concepts and skills</td>
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<td>Includes a complete explanation of the concept(s), terms, and/or skill(s) taught</td>
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<td>Explain item 1</td>
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<td>The explain phase provides a variety of approaches to explain and illustrate the concept or skill. For example approaches might include but are not limited to the use of technology, virtual field trips, demonstrations, cooperative group discussions, panel discussions, interview of guest speaker, video/print/audio/computer program materials, teacher explanations.</td>
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<td>Explain item 2</td>
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<td>The discussions or activities allow the teacher to assess students’ present understanding of the concept or skill through appropriate formative/authentic assessment.</td>
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**Expansion – Phase 3**

(Elaborate and Evaluate)

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**Elaborate Item 1**
There is a logical transition from the explain phase. The elaborate learning activities provide students with the opportunity to apply and extend the newly acquired concepts and skills into new areas.

**Elaborate Item 2**
The elaborate learning activities encourage students to find real life (every day) connections with the new concepts or skills.

**Evaluation Item 1**
The lesson includes summative evaluation, which can include a variety of forms/approaches.

**Evaluation Item 2**
The evaluation matches the objectives. *See back for list of some methods of evaluation.*

**Evaluation Item 3**
The evaluation criteria are clear, appropriate, and measurable (i.e. rubrics)

### Scoring Criteria

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<td>Excellent</td>
<td>Good</td>
<td>Average</td>
<td>Poor</td>
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<td>All elements are present, complete, appropriate, and accurate, with rich details. Another teacher can use the plan as written.</td>
<td>Most of the elements are present, complete, appropriate, and accurate, with rich details. Another teacher could use the plan with a few modifications.</td>
<td>Approximately half of the elements are present, complete, appropriate, and accurate, with some details. Another teacher could use the plan with modifications.</td>
<td>Few of the elements are present, complete, appropriate, and accurate, with few details. Another teacher would have to re-write the lesson in order to implement the lesson.</td>
<td>Key elements are not present. Descriptions are inappropriate. Plan lacks coherence and is unusable as written.</td>
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*Typical inquiry skills - predicting, hypothesizing, observing, measuring, testing, recording, graphing, creating tables, drawing conclusions

*Typical formative assessment methods: science journals, KWL charts, concept maps, writing assignments, art work, drawings/charts, graph, quiz, test, PowerPoint presentation, I-movie, movie, cartoons. Note that evaluation comes from the culmination of the formative assessments used during the lesson.

*Examples of appropriate experiences are: the use of technology, Internet field trips, field trips, hands-on/minds-on learning activities, cooperative group discussions, panel discussions, interview of guest speaker, video/print/audio/computer program materials, teacher explanations, Webquest, Thinker, I-movie, PowerPoint