

WHAT EFFECT WILL USING INQUIRY METHODS OF TEACHING SCIENCE
HAVE ON SIXTH GRADE STUDENTS?

by

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ABSTRACT

How should science be taught? Is it enough to be familiar with vocabulary words and to learn concepts others have figured out? Or should the desire to know be the initiator and sustainer of the learning situation? How should science be taught?

This project studies the effect of using the 5E method of inquiry – Engage, Explore, Explain, Extend, Evaluate – to teach sixth grade students. Of interest was the effect it would have on students' attitude towards science, their understanding of science content, students' data collection and data organizational skills, students' ability to design and conduct a controlled experiment, and the effect on the teacher.

Ninety-seven students were taught two units using the 5E method of inquiry. The results were compared to units that were taught by non-inquiry methods. Student tests, surveys, interviews, and performance tests were considered in the analysis.

The conclusions were that students did improve data collection and organizational skills and in their ability to design and conduct a controlled experiment. Content scores were actually lower for the inquiry unit. Interviews and surveys indicated that students were more engaged in the inquiry units. Survey results showed that students liked science less after the year of school but teacher observations and student interviews confirmed more engagement. Survey results showed that the change in attitude was due to it being more complicated.

The units using inquiry methods took longer to complete than non-inquiry units. The teacher could not just cover the material. Students needed time to process the information and discuss and explore with activities. Inquiry methods created more work for me, the teacher, because I had to alter the activities to make them inquiry, and compile student data to find patterns in student ideas. The misconceptions were more obvious since students were required to explain and discuss, and it took time to deal with these misconceptions. It was exciting work because there was a strong feeling of engagement in the classroom.

INTRODUCTION AND BACKGROUND

School Demographics

I teach an integrated science curriculum to 107 sixth graders. According to the Indiana Department of Education, the school where I teach had an enrollment of 736 students in grades six through eight for the school year 2009-2010. Our school population has declined since 2006, when there were 849 students enrolled in our school. When a well established near-by Pfizer plant closed we lost many students of these professional employees. Of the 736 students that were enrolled at our school in 2009 - 2010, 199 (or 27%) received free or reduced lunches. Nearly eighty five percent (625) of our students were white, 4% (32) were Asian or Pacific Islanders, close to 5% are multiracial, less than 4% (28) were black, 2% (15) were Hispanic and one was an American Indian. Honey Creek Middle School is part of the Vigo County School Corporation and is located south of Terre Haute, a mid-sized city in west-central Indiana. Our students live in the suburbs or in rural areas. The Vigo County School Corporation serves 16,014 students and is composed of 16 elementary schools, six middle schools, three high schools and two alternative schools. Students entering Honey Creek come from four different elementary schools.

I have been teaching science at this school for 15 years. It is the site where I attended and graduated from high school, although the building was replaced in 1993 and it was changed to a middle school. Previously I taught sixth grade math, science, language arts and social studies in Tennessee for 15 years.

Project Background

One of my core beliefs is that students should be experiencing science rather than just learning about it from a detached perspective. Science should include a lot of playtime. Hands-on activities have always been a part of the way I teach. It is a pleasure to be able to lead students into an activity that will result in them discovering something new to them about the real world. I delight in watching them play with dandelion seed parachutes, maple seed helicopters, and observing other methods of seed dispersal. I share their joy when they look into the microscope and see creatures moving in the water that they have dipped out of the pond.

I believe that learning is active, not passive. Students should be led into discovery by curiosity or by trying to figure out how to solve a real problem. Who enjoys memorizing dry terms and filling out worksheets that seem to be detached from real life? The desire to know and understand is a key element of any learning situation. It initiates and sustains learning.

Sure, there are times to memorize information, but the teaching of science should not be a dry introduction from the teacher and an assignment to memorize new terms. This project developed as I pondered what I could do to increase the “wonder” factor for the sixth graders in the given Indiana curriculum. What methods could I use to teach my students how to be curious about the natural world and skilled in finding the answers? What could I do to increase their skills of questioning and observing, as well as collecting and analyzing data?

I had heard about inquiry methods of teaching, but have always believed that these methods were not focused enough or practical to use in a real classroom with 25-30 students and that using methods like that took way too much time. The usual complaint I had heard from

other teachers was that we would not have time to cover the curriculum topics if we taught by inquiry. So all these years, I have dutifully taught the curriculum by teaching facts and vocabulary and giving students plenty of hands-on activities and lab time. Unfortunately, until the last few years, I did not consider if students had any desire to learn or not! But, it has been increasingly important to me the last few years to at least try to get students ready to learn before the lesson. So gradually my research question took form. What I wanted to know was: What effect will using inquiry methods of teaching science have on my sixth grade students?

Sub-questions were:

- 1) What effect will inquiry methods have on their attitude towards learning science?
- 2) What effect will inquiry methods have on their understanding of science concepts?
- 3) What effect will inquiry methods have on the students' data collection and data organizational skills?
- 4) What effect will inquiry methods have on students' ability to design and conduct a controlled experiment?
- 5) What effect will inquiry methods have on the teacher?

As teachers, we lament curriculum that is "an inch deep and a mile wide." Can a different approach to teaching help change that reality? If inquiry teaching can be shown to increase the depth of the curriculum without significantly changing the length, then that would be valuable information to share.

In the past, my students have had many hands-on activities and much lab time. A major difference in the way I implemented inquiry methods for this research project is in the active participation of the students. Instead of throwing out information like I was "slopping the hogs," I engaged them in the unit beforehand by demonstrating curious phenomena, and waiting for

them to ask the questions. Teaching by inquiry, as I see it, is getting the students thirsty to know, before the lessons are presented. Once they are hooked, will they be willing to think about how to find the answers? Will they willingly design experiments to test what they think? Will they carefully listen and critically consider explanations given by classmates? Will the textbook become a welcomed source of information instead of a duty to read? Will students retain the content better? What will this do to their attitude towards science? Can teachers realistically teach this way in a regular-sized classroom? I had many questions about using inquiry learning. This research project gave me the chance to collect and analyze data to better answer at least some of those questions.

CONCEPTUAL FRAMEWORK

In the high tech world where we live, science education is very important. According to ABC news (Bruce, 2010), China ranks first and the United States ranks 20th in teen performance in science. Because of this, President Obama said in his State of the Union address that we again have our “Sputnik moment” (State of the Union, 2010). The President wants to invest in science education in order to improve our expertise in research and development when compared to the other nations of the world. Our desire to be number one in science education prompts us to consider changes in the educational system of our country.

Numerous perspectives result in a great variety of suggestions to improve our worldwide educational standing, especially in science and math. Critics believe that a business model of education would be more successful. Some other possible solutions to improving education include extending the school year, holding school on Saturdays, keeping students in school for longer hours, intensifying education of students in the pre-school age range, rewarding teachers

with pay increases if their students excel, cutting funding for schools that don't perform, and doing away with public education in favor of charter schools.

Following are published studies and methods tested in classrooms which help to establish the effectiveness of using inquiry methods in teaching science. There is not total agreement on the effectiveness of these methods, perhaps because there are many definitions of inquiry science. Yet, the literature shows strong support for leaving the more traditional passive methods of teaching science in favor of using more active methods, such as inquiry methods.

The National Science Teachers Association (NSTA) approaches educational reform with suggestions for pedagogical changes. Using inquiry methods is one recommendation. Following is part of the NSTA position concerning inquiry teaching.

Scientific inquiry is a powerful way of understanding science content. Students learn how to ask questions and use evidence to answer them. In the process of learning the strategies of scientific inquiry, students learn to conduct an investigation and collect evidence from a variety of sources, develop an explanation from the data, and communicate and defend their conclusions. The National Science Teachers Association (NSTA) recommends that all K–16 teachers embrace scientific inquiry and is committed to helping educators make it the centerpiece of the science classroom. The use of scientific inquiry will help ensure that students develop a deep understanding of science and scientific inquiry (NSTA position statement, 2011, Scientific Inquiry, Introduction, para. 3 and 4).

In Indiana, there is a strong shift toward using inquiry teaching methods and project based learning. Our corporation, which includes the middle school where I teach and five other

middle schools, examined available science textbooks for adoption for the school year 2011-2012. Of all the publishers who have presented materials, only one publisher offers a hardback student edition. The text in that book is expanded by inserting multiple places for students to respond or conduct inquiry investigations. Several publishers offer softbound consumable student editions in which students respond frequently in the consumable text with predictions, observations or conclusions. Several publishers have online student texts only. All publishers emphasize inquiry learning. Indiana Science, Technology, Engineering & Mathematics (I-STEM) is promoting the use of rotating kits that are inquiry based (Indiana STEM, 2011). So it is very obvious that teaching science by inquiry is considered important here in Indiana.

Some definitions of inquiry are necessary at this point. Depending on the amount of structure imposed on the investigations, inquiry can cover a large range of investigations (Lott, 2011). In confirming inquiry, students investigate to confirm previously learned material. Structured inquiry occurs when the teacher provides the questions and procedures, but students reach their own conclusions based on the results of their investigations. In guided inquiry, the teacher provides the questions and students design and conduct their own investigations to determine the answers. Open inquiry allows students to generate their own questions, and design and conduct investigations that lead them to conclusions based on their evidence. Teachers choose the best inquiry method to use in each situation. If students lack background knowledge and skills for investigating, then teachers must scaffold the learning appropriately until students are actually able to conduct open inquiry investigations.

I have chosen to follow the 5E Method of Inquiry. Figure 1 helps to clarify that method. More information about this is given in the methodology section.

Table 1
5E Method of Inquiry (Adapted from Coe, 2001)

METHOD	DESCRIPTION
Engage	Object, event or questions used to engage students. Connections facilitated between what students know and can do.
Explore	Objects and phenomena are explored. Hands-on activities, with guidance.
Explain	Students explain their understanding of concepts and processes. New concepts and skills are introduced as conceptual clarity and cohesion are sought.
Extend	Activities allow students to apply concepts in contexts, and build on or extend understanding and skill.
Evaluate	Activities permit evaluation of student development and lesson effectiveness. Formative or summative assessments.

Teaching science through inquiry is not just providing hands-on activities for students. It is more. It is designing experiments and talking about it. It is reporting on their investigations, reflecting, and making and communicating self assessment (Joseph, 2010). This differentiation of hands-on activities and student driven investigations with dialogue makes inquiry learning much more than hands-on science. Experiencing the processes that scientists use will be helpful of course, but according to what others say, unless we explicitly talk about what these processes are, we won't really be any closer to students understanding the nature of science. In other words, they will not automatically make the transfer that what they did was real science, not just a fun activity (Lee, 2009).

Students need to know how to design and conduct controlled experiments. In order to do this, they must be able to identify variables, and consider how to keep variables constant that

would interfere with the results. Making data tables, collecting, organizing and analyzing data should be valuable tools for their investigation, not simply a math or science assignment.

Learning science facts is certainly important, but students need to learn how scientists identify and establish these facts. It is scholarly and fun to be curious about the natural world, ask questions, and seek the answers by investigation or by research. Not all teaching strategies need to be inquiry-based, but teachers should engage students in the process by asking open-ended questions, encouraging students to make hypotheses, listening to students support their hypotheses with data, and providing time for discussions in small groups or pairs (Brown, Hershock, Finelli, & O'Neal, 2009). Teaching science by inquiry methods will not only increase their knowledge base of scientific facts, but it will bolster student confidence in their ability to discern knowledge.

Not all evaluations of inquiry methods are favorable. An article published in the "Educational Psychologist" says that it is not an effective way to teach (Kirshner, Sweller & Clark, 2006). The authors base their conclusions on the way they perceive that people learn. They claim that unguided activities actually cause people to lose memory. Strong guidance is needed, they believe. They say "Not only is unguided instruction normally less effective; there is also evidence that it may have negative results when students acquire misconceptions or incomplete or disorganized knowledge" (Kirshner, Sweller & Clark, 2006, p. 84). They cite various studies conducted in math and science and suggest that only ideology prompts educators to use inquiry methods, not research studies.

Studies done by the National Science Resources Center, with students in Delaware, California, Pennsylvania and Wisconsin refutes the above argument with data that confirms that inquiry-based instruction in science actually improves science achievement. One study was

conducted in three Philadelphia middle schools with students in fourth through seventh grade. The students who participated in this study were from high-poverty urban schools. Students at every level showed significant improvement the first year of the study, when compared to a control group. Improvement in scores continued to increase the longer that inquiry methods were used (Ruby, 2006). Similar results were found with their other studies.

A study that involved 1700 students, 12 high school teachers and 12 middle school teachers showed that those using a guided inquiry based lab scored significantly higher on post tests and had better long term retention than students taught with more traditional methods (Blanchard, Southerland, Osborne, Sampson, & Granger, 2010).

What successful experiences do teachers have to share about using inquiry methods in their classrooms? One example, used with elementary children, but easily adapted for older children, used inquiry methods to allow children to explore three different topics: moon exploration, animal classification and plant growth (Palmeri, 2009). This teacher identified the importance of asking students to “collect, organize and make sense of their own data” (Palmeri, 2009, p.32). Instead of telling them which data was important, students had to decide. Children also had to measure or describe their data in a logical way. In the process of doing this, they were given the “opportunity to explore many different organizational strategies and the benefits and limitations of some strategies...” (Palmeri, 2009, p. 32).

Last year students of mine said to me that they did not like to take the time to make graphs, because it was a lot of work and not useful to them. An activity used with high school students demonstrated the importance of making graphs to help them understand and analyze data. Diane Riendeau (2007) implemented an activity involving several steps that helped her students see the value of organized data. She first gave them a set of written data analyses and

asked them to draw conclusions from it. It proved very difficult at first. Then she gave her students the same data analyses in the form of a table, but in random order. Suddenly the material began to get clearer. The next set of information she gave them was the information in an organized table, with the final form as a graph. This beautifully illustrated the point that organized data helps scientists see patterns and make predictions.

Jeff Thomas created some lab handouts for prompting and guiding students through the process of learning by investigating. These handouts help students and teachers who are unfamiliar with inquiry. It guides them in designing testable questions, planning, graphing and communicating their findings (Thomas, 2010). Because many teachers and students are unfamiliar with inquiry methods, these handouts can be valuable supplements.

The editor of Science Scope says, “Middle-level students can analyze existing data as well as collect it first-hand so they can better understand natural phenomena and the methods we use to study them...., {They can} relate data collection and analysis to natural and real world situations.” Using inquiry methods to teach students is both feasible and appropriate. “This approach will help link curriculum content and scientific processes and will make the task of evaluating and interpreting evidence much more interesting and meaningful to students” (Liftig, 2010, p. 1).

Several science teachers constructed and implemented a lesson plan on sound using the 5E method of inquiry. They viewed science as a three-legged stool: one leg as science content, one leg as inquiry processes and skills and one leg as the nature of science. They described in detail how the lesson was conducted, and concluded that “This lesson shows that students can simultaneously learn science content and do inquiry while learning how scientists construct their knowledge claims” (Sikel, Lee & Pareja, 2010, p. 63). Teachers who implement inquiry

methods find that these methods help students learn several facets of science at once. Students learn content, processes and gain understanding of how scientific facts are established.

Why are some teachers reluctant to use inquiry methods of teaching? One big factor is the time required to use these methods. This type of teaching takes a lot more time and a lot more effort than just teaching the facts from the textbook. For example, Akerson and Hanuscin (2007) reported that teaching one of their specific lessons by the hands on method would take 30 minutes. Compare that to an inquiry lesson including a discussion of how the activity was like what scientists do, and the lesson takes two and a half hours (Akerson, 2007)!

Another concern is how to actually go about using inquiry methods with the expectations imposed by schools. Teachers are required to teach specific standards at specific levels. How do teachers allow students to initiate questions to be studied while still accomplishing the curriculum mandated by the school corporation? Perhaps the way to use inquiry methods with the current curriculum is for teachers to gain expertise in guiding students to ask testable questions.

One author says that “Teachers can help students ask investigable questions by modeling the way a scientist would ask them. During a lesson on the study of liquids, for example, a teacher might ask, ‘Do all the liquids you are studying evaporate at the same rate?’ or ‘I think the alcohol will evaporate more quickly. How can we find out if it does?’”(Lowery, 2010, p.8). Here, the teacher knows the answer, but instead of giving the answer, the teacher models the way a scientist would ask an investigable question, and then allows the students to participate in an inquiry investigation to find the answer. Using this technique, students then learn by copying the modeling of the teacher—how to ask questions that can be answered by inquiry. When students generate their own questions, the teacher should consider whether or not

a particular question could yield answers to students based on the resources available to them. If so, students would be allowed to engage in this open inquiry investigation. If not, the teacher should explain how to locate knowledge from materials written by others. Following these guidelines whenever possible integrates inquiry methods in to the program while following the mandated curriculum.

There is no quick fix to teaching students how to take their natural curiosity and initiate their own investigable questions. It will take time and practice. One or two treatments a year will not meet the students' needs to be an effective inquirer. "Direct inquiry experiences lead students toward independence, develop their self-confidence, and provide knowledge that is memorable (not that has to be memorized) because to do an investigation is personally satisfying and meaningful" (Lowery, 2010, p. 9).

In a publication prepared for the faculty of the University of Michigan by the Center for Research on Learning and Teaching, (Brown et al., 2009) the authors claim that teaching by inquiry methods results in greater student understanding and retention, and in the development of stronger critical thinking skills. They also state that all the teaching need not be done by inquiry methods, in order to see these gains. Integrating inquiry methods with other methods encouraged students to be more persistent and confident in their work and result in more success overall.

As I strive to improve my teaching methods, I am encouraged by the writings of others to use inquiry methods of teaching science. Even if I cannot totally convert all my lessons to inquiry, from the literature it appears that I can integrate inquiry methods into my strategies and expect my students to benefit from them.

METHODOLOGY

At the beginning of the school year I taught an integrated science curriculum to 107 students. That number got smaller during this project as students moved to other schools. No new students were added to my study, even though I did have new students enroll during the year. Unless they were in my classes from beginning to end, I did not count their data.

According to the Indiana Department of Education, in October of 2009 the school where I teach had an enrollment of 736 students in grades 6-8. Of these students, 199 (or 27%) received free or reduced lunches. Most of our students are Caucasian, with a small percentage of Asian students and a smaller percentage of black and Hispanic. We are located south of a mid-sized city in west-central Indiana, and our students live in the suburbs or in rural areas.

I chose to include all of my students in this study, because I wanted the largest sample possible. These 107 students were divided into four classes that met for 45 minutes every day. Boys and girls were about even in number, with 53 boys and 54 girls. Ninety-eight of these students were Caucasian, six were Asian, two were Hispanic and one was African American. By the end of the year, I no longer had the same group of 107 students that I started with. From the original group, I ended up with 97 students: 47 boys and 50 girls (90 Caucasian, five Asian, one Hispanic, one African American).

The research methodology for this project received an exemption by Montana State University's Institutional Review Board, and compliance for working with human subjects was maintained.

On the first day of school I involved my students in an activity meant to startle them with its unexpectedness and engage their brains as they tried to figure it out. I walked around the

room with two clear glasses on a platter. Each glass contained a clear liquid. In one glass, the ice cubes floated, which is what we expect to happen with water. In the other glass, the ice cubes were on the bottom of the glass. Students were asked to draw what they saw, noting the similarities and differences in each glass. Then they were asked to explain what was unusual to them, and make some predictions about why this phenomenon occurred. After they had drawn and written, I asked for them to share what they had written. They expected me to tell them the answer at the end of class, but I did not. Instead I told them that they probably had all the materials at home to create the same situation. I suggested that they experiment and let me know the results.

This was just the beginning of the year. My methods of teaching obviously startled my students on many occasions. Some were intrigued, some confused. They expected me to tell them facts, which they would then learn and repeat to me on a final test. Asking them questions and leaving the questions unanswered unless they pursued them was unsettling to many.

My initial plan was to give students a pre-survey, followed by teaching the nature of science in chapter one using inquiry methods. However, life got in the way and plans had to be changed! Early in the school year I was diagnosed with uterine cancer. I was able to gather baseline information about my students by using their Cognitive Skills Index (CSI) scores from the spring (CTB/McGraw Hill, 2011), giving performance tests, and by giving a chapter test on the nature of science and by their responses on the survey, “What do scientists do?” (Appendix A) and “What about science fairs?” (Appendix B). Substitutes taught my classes intermittently while I underwent medical tests and procedures. I was not able to implement an entire 5E unit as shown in the following table until after I returned to work full time after the Christmas break. After Christmas break, the interruptions continued! Intermittent snow days, a massive

nationwide storm that closed our school for a week, one or two hour delays in the starting time of school due to weather, and other changes to our schedule also hindered progress.

I chose to use the 5E model of inquiry, as this model seemed to me from the literature review and from my experiences to be the most effective way to implement inquiry methods in the classroom.

Here is an explanation of what the 5E model of inquiry looks like. The teacher begins by *engaging* students with a discrepant event, or some activity that causes them to pause and wonder. It is an attention grabber. Students verbalize what they currently know and believe and offer evidence to support those views. Once the teacher has their attention, she proceeds to the *explore* stage by providing investigations that require students to collect and analyze data to further their knowledge of the subject. Students again verbalize learning, and the teacher intervenes to clarify any misconceptions students may have. Learning is evidence based. After these initial investigations, the teacher *explains* known facts and phenomena, and introduces vocabulary that facilitates discussions of the topic. She expands the concepts with other information, including information found in the textbook and information that is currently available but not feasibly investigable by students. In the *elaboration* stage, students continue to expand their knowledge and skills with investigations and research of related topics. The evaluation of the process may include performance tests and/or responses to questions in a standard unit test. These steps may repeat themselves in cycles or in partial cycles, depending on the topic.

Before I left for medical leave, all I was able to do was to involve students in activities that would engage their curiosity, and ask them to write questions that they had about the topic, and suggest ways of finding the answers. I used inquiry methods of engagement, questioning

and exploration, though I could not follow through with any complete unit of treatment, since I had to miss school randomly until October 25, due to diagnostic procedures. A substitute totally took over my classes beginning with the second grading period on October 25. I returned to my classroom in January. I taught for about a month, and then had to have an additional surgery on February 9th. I returned to work full time, about two weeks later on February 24. My substitute for this time was not a science instructor, but read aloud some of the material for the Electricity unit. She was not knowledgeable enough to correct any misconceptions, but she guided them in the readings and assigned and checked review sheets. Reading the text aloud to the students is important, since our text is written at a reading level that is above the sixth grade level. She learned with them, and I encouraged her to back up and re-read sections that did not make sense to her. If she did not understand it, I told her that they might not understand it either, so to feel comfortable slowing down and modeling how to make sense of new material.

Since my first long term substitute taught my classes in a more traditional way, I have chapter test scores from her that I compared to test scores of the two chapters that I taught using inquiry methods. In the student post surveys, and in the interviews, students were able to comment on how each method of teaching affected them. The second substitute helped to lay the groundwork for our study of electricity.

The treatment involved two units taught using the 5E method. First I taught a unit on the Atmosphere, and then a unit on Electricity. The unit plan in each case uses the 5E scaffold. The plan includes the objectives, vocabulary and skills I was working on. Below is the how the actual implementation of the unit plan took place for me.

The unit on Atmosphere began on Monday, January 3. I have numbered the days instead of giving dates, to simplify. See the timeline of the unit below. Some words are italicized to indicate the E from the 5E model of Inquiry.

Day 1- Atmosphere unit

I *engaged* students with questions about what causes wind. I turned on a fan and asked students to explain in discussion why it caused wind. Then I drew on the chalkboard a picture of personified wind blowing air (Figure 1). Finally students were told to answer this question on notebook paper: How does outside air move? What evidence do you have for this? Do clouds blow air? Is there a giant fan in the air? What do you think? Students wrote for the rest of the period. I collected the papers, and read them overnight and tabulated the patterns I found in their thinking.



Figure 1. Personified wind. (www.wapa.gov/es/pubs/esb/1998/98Apr/Graphics/wind.gif)

Day 2

I commented on what students shared in their papers. Students were challenged to *explore* their questions by devising a way to test what causes the wind. They were told to write their procedure, list the supplies they would need, draw a picture of the set up, and list any safety precautions they should take.

Students were very unsure about how to do this. They stumbled through this task in groups of four or five and turned their paper in by the end of the class period. I used this activity as formative assessment to guide my teaching.

Day 3

Each group of students took its turn presenting the format of the experiment they had designed. Other students and I questioned them at the end. I praised them for their work and gave grades on their effort. Most were very primitive attempts.

We read the lesson in their text about winds, starting with an *explanation* about land and sea breezes, because they would be most familiar with breezes around the many coal strip mine lakes in our area. Then we continued to read and *explain* global winds, etc.

Day 4

We continued to discuss winds, using the text. The Coriolis effect on winds was *explained* by comparing it to a merry-go-round and *explored* by having students work in pairs to model it. In the pairs, one student would put a pencil on a dot in the middle of the paper, then close his eyes and draw a straight line to the bottom of the paper while the partner rotated the paper. They repeated it going up, and changed jobs and repeated it. They noted the curved line that was drawn each time and noted in their journal what they did and how this related to global winds.

An exit card (Classroom Assessment Technique or CAT) was required at the end of the period. Students answered this question on an index card: What is one thing you learned in science class this week that you know you will remember?

Day 5

To engage students on the next lesson, they wrote in their journals questions they or I had about how the sun's energy gives us heat on earth and what the heat has to do with climates, wind and the water cycle. Why doesn't it freeze every night when the sun is not shining on us? How can water evaporate when the ocean is not boiling? Why are the temperatures of hot

pavement and wet sand different from the temperatures of lake water or soft green grass? Then they shared their thinking in a class discussion.

I used the lesson from the text (Biggs, Daniel, Feather, Ortleb, Snyder & Zike, pp. 87-90). The objectives are: Describe what happens to the energy Earth receives from the Sun (Fifty percent is directly or indirectly absorbed by Earth's surface, 25% is reflected from clouds, 15% is absorbed by the atmosphere, 6% is reflected by the atmosphere, and 4% is reflected from Earth's surface). Compare and contrast radiation, conduction, and convection. Explain the water cycle and its effect on weather patterns and climate. Vocabulary words: radiation, conduction, convection, hydrosphere, evaporation, and condensation.

Student homework was to think about questions they would like to investigate about wind or air and water temperature or how the sun heats different places on earth.

Day 6

We reviewed concepts they had learned so far. I realized from their experiment designs that they needed more help understanding a controlled experiment. Students were given the template (Appendix C) for designing an experiment. We discussed this, particularly stressing what would be measured in an experiment and how it would be measured. We talked about testable questions, questions that could be tested by those who had more sophisticated equipment, and the importance of studying what others have investigated and documented as we learn about science.

Day 7

From what students suggested, I chose four testable questions, one for each class, and with their help we worked through designing an experiment using the template, "Design an Experiment" (Appendix C). They wrote on their paper as I wrote on mine. I did not believe that

they had the skills to do this process in small groups. So I chose to model the process with their input. Many changes were made as we worked together. When I recognized a problem in the design, I would ask them about its effectiveness and get their input to improve it. Often students noticed problems that I had not anticipated. I kept all students engaged as much as possible by asking them what they wrote or what they thought about parts of the design.

Day 8

I showed a two minute video clip about jet streams and reviewed that concept.

We finished the group designed experiments together. One group got stuck, and I could not figure out how to solve the problem myself, so it was eliminated from the ones we would actually test. I asked for input from other teachers, but could not settle on an activity that I thought would be safe and manageable with my students.

Day 9

At this point I hoped students would be wondering exactly what air is made of and why it is so important to us. I *engaged* students by asking them what they knew about the air or atmosphere surrounding different planets in our solar system. I used the internet and projected information from the computer to the large screen, about the atmosphere on different planets. Students composed questions about what they would like to know about the Earth's atmosphere and these were written on the board. I complimented the many questions they generated and reminded them that many questions about the atmosphere are questions that require equipment that we don't have. So, we are fortunate to have information in our textbook and other references to answer our questions.

The next lesson in our text is entitled Earth's atmosphere. The objectives were:

identify the gases in Earth's atmosphere, describe the structure of Earth's atmosphere, and explain what causes air pressure. Vocabulary words were atmosphere, troposphere, ionosphere, ozone layer, ultraviolet radiation, chlorofluorocarbon, and pressure. I used the text to *extend* student learning and *explain* these concepts. I reminded students about the experiments they had done with Bernoulli's law when we studied aviation earlier in the year.

Day 10

I typed up the experiments that each class had designed and set up five lab stations for students to *explore*. Two were designed by one class and were entitled: "How does the heating and cooling of land and water compare?" two were designed by another class and were: "How does salt affect the temperature of ice?", and one lab was designed by a third class: "How do the Sun's rays affect the temperature of the earth at different latitudes?" The one we scrapped was the one the fourth class was working on called "What happens when cold and warm water (or air) meet?" We just could not figure out how to safely and manageably test this last one in our classroom. Students chose which group they wanted to work with, as long as students were evenly distributed in the groups.

Day 11

Students stood in front of the class and presented the results of their experiments. After all of the experiments had been presented, we discussed problems in the way the labs were written and students suggested ways to fix those problems with a better designed experiment. I made note of those suggestions and re-typed them so students could re-do the labs.

Day 12

Students were given a performance test on making a graph from a data table. When they finished that and turned it in, they began working on selected chapter review questions from the textbook, and finished them for homework.

Day 13

We checked the homework together and discussed misconceptions.

Students were given five UltraViolet (UV) sensitive beads and a stretchy craft loop cut in half to string them on. They were instructed to draw and describe the beads in their journals, and then record any changes that they noticed that occurred with the beads. Changes were to be specific and the situation that caused the change to be tested to eliminate coincidence factors and determine the exact cause of the change.

Day 14

Students tested the same questions they had tested before. The difference was that they had rewritten and refined the experiments.

Day 15

Students presented their results to the class. I showed them the results I had gotten when I did it, and compared my data tables and graphs to their work. It was more satisfying for them to do the improved labs a second time. Their first experience was familiar to them, and they had as a group suggested the improvements. They did a better job recording data and making appropriate graphs. They were appreciative of seeing my results, because that represented to them the “correct” results. There was a sense of accomplishment on their part. .Even though they had struggled with the labs, there was a sense of ownership in the process, and they were

eager to examine my results and compare them to their own. There were many questions and comments from the students.

We had a discussion about what changes occurred in the UV beads (which I referred to as white beads when talking to the children). Most students noticed that the beads changed colors. Many were convinced it was the cold temperature that made them change colors. Others argued that they knew it was not the cold temperature, because they put them in the freezer for awhile and they did not change colors. Other theories they tested were wetness, heat and pressure. It was fun to hear students defend their tests. I did finally share with them that the beads were sensitive to ultraviolet light,

Day 16

My classes took the chapter test online in the computer lab (Appendix D). They also completed the survey, “What helps you learn?” (Appendix E). When students completed their test and submitted it, it was immediately graded and they could both see the grade and review each question they had missed with the feedback given to them. The grade was added to their total score and they could know their current overall grade in the course as well. The survey was not counted as part of the grade.

This is the end of the timeline for the Atmosphere unit.

Not everything worked as I had planned. Adjustments in my original plan for execution had to be made in order for student success to occur. They did not have the skills I expected them to have, so I had to backtrack and teach those skills before we could proceed.

The second unit, in which I again used the 5E Method of Inquiry, was a unit on Magnetism and Electricity. The actual implementation can be seen in the following timeline.

Day 1 - Electricity and Magnetism

The unit began with an engagement activity. Each pair of students was given one D cell battery, one piece of insulated wire about 15 cm long with the insulation cut off about a cm on each end, and a tiny flashlight bulb. Their task was to figure out at least three ways to make the light bulb light, with just those materials. When the bulb lit up, they drew the set up in their journal. The first group to find a new way to light the bulb also drew the set up on the chalkboard. Even though they got the bulb to light, if their drawing did not show a continuous path for the electricity to flow, I challenged them to demonstrate to me with the materials how their set up worked. When they showed me, I pointed out any discrepancy in the drawing and the actual materials, and they corrected the drawing.

When everyone was successful in lighting the bulb at least two ways, we talked about what worked and what did not work. Until they figured out that it had to start at one end of the battery and make an unbroken line to the other end of the battery, some insisted that their battery was dead. We discussed whether or not it mattered what part of the wire touched, what part of the bulb touched and what part of the battery touched, and noted what materials each of those parts were made of.

The text was referred to at this time and the vocabulary words electric circuit, electric current, insulator and conductor were explained with pictures and words in the text.

Day 2

I reviewed the events and learning of the last class period. I questioned them about what they knew about static electricity, lightning, current electricity, insulators, and conductors. They asked me questions about electricity, which I used to question the rest of the class, and

encouraged students to put together what they knew about the topics. I shared information in the text to help complete what students had said in answer to their classmates' questions.

Days 3-5

I was out of school again due to medical leave. My substitute began reading aloud the chapter and discussing the content and explaining the vocabulary words. Since I am not sure exactly the time frame or the methods used on the days when I was not there, I am simply telling the lesson plans I left for those days and sharing the objectives and vocabulary of the lessons. On days three through five she read aloud from the text, and they worked on and checked review sheets.

The objectives of lesson one were, describe how electric charges exert forces on each other, define an electric field, explain how objects can become electrically charged, and describe how lightning occurs. Vocabulary words were atom, charging by contact, charging by induction, insulator, conductor, static charge, and electric discharge.

The objectives of lesson two were to describe how an electric current flows, explain how electrical energy is transferred to a circuit, explain how current, voltage, and resistance are related in a circuit, and distinguish between series and parallel circuits. The vocabulary words were electric current, electric circuit, electric resistance, voltage, series circuit, and parallel circuit.

Objectives of lesson three were, describe how magnets exert forces on each other, explain why some materials are magnetic, describe how magnets become temporary magnets, and explain how an electric generator produces electrical energy. The vocabulary words were mechanical energy, magnetic domain, electromagnet, and electromagnetic induction.

Day 6

Review sheets were graded, then the substitute gave each student 4 circular ceramic magnets and they used them to test and complete the Magnet Experiments activity sheet which I had written up for students to use as an *explore* activity (Appendix F).

Day 7

They watched a video on Electricity and Magnetism. At the end of the period, students were asked to consider all they had learned in the electricity and magnetism chapter. On an index card they responded to these two prompts: One fact I learned from this video is, and I still wonder....

Day 8

I began the class by asking (*engage*) if anyone had ever heard of or seen an electromagnet. Some had, and some had not. I showed a two minute video clip *explaining* how an electromagnet worked and showing one at work in a metal scrap yard.

Then students *explored* by building a simple electromagnet using a D cell battery, and a wire and used it to pick up paper clips. They shared results at the end of the class.

Day 9

We read aloud together the handout from the book, “Reinvent the Wheel” entitled Electric Motor (Kassinger, 2001). It was the history of Thomas Davenport and the events that led to his inventing the electric motor. Students took notes on the paper, underlined key words, and jotted down thoughts and questions. Their homework was to review the steps of the experiment they would do on Tuesday to make their own electric motor with a D battery, magnets and magnetic wire. I told them that from my experience, the diligent students who kept

thinking and adjusting would be successful in making the motor work, but not all students would be successful. Understanding what to do ahead of time would increase their chances for success.

Day 10

In pairs, students *explored* how to make a simple motor by using the instructions and by making necessary adjustments. About half of them were successful!

Day 11

I directed the grading of the review handouts and used student mistakes to identify areas that needed clarification. I reinforced what they knew and used other methods to explain what they did not yet understand. We discussed their experiences making an electric motor and an electromagnet.

Day 12

Students completed the lab, “Magnets and Electric Current” in their textbook (Biggs, et al., 2005 pp. 582-583). The purpose of this lab was to observe the effects of a bar magnet on a compass, observe the effects of a current-carrying wire on a compass and observe how the relative motion of a magnet and a wire coil affects a compass.

Day 13

Students presented the results of the lab they did on Friday. We compared and discussed the difficulties encountered, the results and the conclusions and applications. We prepared for the next day’s lab by reading aloud the objectives and previewing the procedure.

Day 14

When students wrote questions that they would like to investigate concerning electricity, many of them wondered about how the arrangement or number of batteries would affect the brightness of the light, so I was very pleased that there was student initiated interest in finding

the answer to the lab, “Batteries in Series and Parallel” (Biggs, et al., 2005. pp. 581). Students completed this lab in class. They connected batteries end to end and noted the brightness when compared to a brightness tester they made. Then they connected the batteries side by side and again compared it to their brightness tester. An alteration I made was that they needed to make and record data in a data table. The text simply says to “record your observations”.

Day 15

Students shared results of yesterday’s lab. We discussed the conclusions and application of this lab. They predicted that if we continued to add batteries end to end, that eventually we would blow a light bulb. Because of limited resources on hand, that was demonstrated after students suggested it.

The lesson summaries were read aloud. They completed review sheets to help focus their study for tomorrow’s test.

Day 16

I collected their review sheets. In the computer lab, students first took their chapter test on Electricity and Magnetism (Appendix G). Then they took the post-test for Chapter 1 (Appendix H), which was a post-test. The final activity was to complete the post-survey, “What do Scientists Do? (Appendix A).

Comments about methodology

If I had been able to implement the entire Electricity and Magnetism unit without a substitute, then the order would have been different. I could have sequenced the order of *engage, explore, explain, extend* to repeat itself many times and in a more logical order. Perhaps I could have taken the “cookbook” labs from the textbook and altered them more to be inquiry. But one did require the completion of a data table, and I required it on the other, and this was

good practice for them. Plus, sharing results and discussing conclusions is an important part of inquiry, and we did that. And, even though there were textbook activities, allowing students to explore these concepts with lab activities was very valuable to them. Some teachers, and certainly my non-science-proficient substitutes, would be content to deliver the material from the text without students ever touching batteries and magnets, or gaining experience handling wires, bulbs, magnets and compasses. I was using inquiry methods by providing experiences for them to explore what the text meant with real objects, facilitating brainstorming sessions and requiring that they share and discuss the results.

That explains the actual implementation of the treatments. The next section explains the triangulation of the data collection instruments I used to answer the research questions.

Research Design

Because there is no control group to compare my research with, it is important that I use several sources of data to answer each of the questions. Table 2 shows how that triangulation of data was done.

Table 2
Data collection instruments triangulation matrix.

Data collection instruments that will be used to answer the questions.	What effect will using Inquiry Methods of teaching science have on my sixth grade students?	1) What effect will this have on their attitude towards learning science?	2) What effect will this have on their understanding of science facts and concepts?	3) What effect will it have on the students' ability to collect and organize relevant data?	4) What effect will it have on the students' ability to design a controlled experiment?	5) What effect will it have on the teacher?
CATS	x	x	x	x	x	
Student questionnaires and surveys (pre and post)	x	x	x	x	x	
Chapter tests on chapters I taught using Inquiry Methods	x		x			
Performance tests	x			x	x	
Chapter tests of chapters taught by a substitute and tested while I was on medical leave	x		x			
Student journals	x	x	x	x	x	
Teacher journal				x	x	x
Terra Nova tests (CSI)	x		x			
Student interviews	x	x	x	x	x	

The Terra Nova test (CTB/McGraw Hill, 2005) is a standardized test that is given to our students every year to determine their ability to learn. They are asked to identify patterns, and answer questions that require reasoning, not knowledge. The results of this test give us their Cognitive Skills Index (CSI) scores, which is an estimate of the intellectual ability of students. This test is a nationally used test and is considered to be very valid and reliable in determining general student ability in academics.

The survey, “What do scientists do?” was designed by me and given to students online on the computer. I designed it to help me determine student attitude towards learning science in school, student understanding of the ability and limits of science to find answers and to discover student perceptions of the methods scientists use to establish facts. I tried to mix in easy, no pressure questions to relax the students. I did not think that my results would be valid if students were stressed about being right. When I saw that student responses showed very little understanding of scientific methods, I designed and administered the test, “What about science fairs?” to be sure that the information I got was valid. I wanted to rule out the possibility that they only knew scientific methods in the context of science fairs.

Each of the chapter tests were compiled by me. Students logged in at this website, <http://www.rose-prism.org> to access the course I designed and to take tests. The tests consist of questions from the student textbook and review sheets, as well as original questions I wrote. Some questions were multiple choice, some were true/false, and some were matching. Occasionally I had a question that says to pick all that apply, from a list of choices. Some answer choices are light-hearted and obviously not correct. The humor helps remove anxiety and as a result students relax and performance is more reliable. When designing the tests, I aligned them to test the objectives that were listed at the beginning of each lesson. Students knew that they could study the objectives and the vocabulary and review class activities to prepare for each test. This helps to make the results valid in testing science content. I tried to create questions that required higher level thinking skills. I wanted to separate what they knew by memorization from what they knew and could use to reason. Looking back, I think they were not valid in testing whether or not students had a working knowledge of science content, because the tests had a larger number of lower level thinking questions. They did test memorized science

content. However, I question the ability of the tests to assess student gain in ability to *do* science. Performance tests, student surveys and interviews were better measures of these areas.

I gave all tests online in the computer lab. The opportunity for students to copy is minimized because the computer scrambles the order of the questions and the order of the answers. The substitute was given two versions of a typed copy of each test and students took paper tests under her supervision. She was instructed to alternate forms of the tests that she gave to students so that copying would be difficult.

Classroom Assessment Techniques, (CATS) are quick ways of assessing formative learning. There are a variety of CATS that I used. All of them are quick written assessments. Usually the answers are written in the last few minutes of class on index cards. These were not done for a grade and spelling was not an issue. They were done to help me identify progress in learning. I could quickly read the cards, identify concerns and address them the next day.

Because I wanted to know how students were progressing in their ability to organize data in charts and graphs, I also gave students performance tests. Students were given some data and were asked to demonstrate that they could make tables and graphs and enter the information correctly.

Throughout the year I kept a journal, which I wrote at the end of the day. Immediate recording of my insights and frustrations give me a valid account of what was going on from my point of view. Students were asked to keep a journal of learning, which they referred to during class discussions. I regret that I did not ask them to keep a reflective journal as well.

To assess student reaction, I interviewed three small groups of students. The first group was three boys and two girls, and the last two groups were three boys and three girls each time. There were 17 total students interviewed in these small groups. The first two groups were

randomly picked from volunteers. The last group was hand-picked honor roll students. I asked each group four main questions (Appendix I), and also asked impromptu questions when needed. They provided general information about student appraisal of the impact and effectiveness of the inquiry methods I had used throughout the year, and were very helpful. Sixth graders are comfortable sharing their thoughts. When students were interviewed, they understood that they were free to answer honestly, and that none of their responses would affect their grade. They actually enjoyed telling me what they thought, and clamored to be chosen to be interviewed.

Validity and reliability were maintained by triangulation of my instruments, plus having colleagues provide feedback.

Students who were interviewed were videotaped so that I could go back and establish quotes exactly without having to stop and take notes. I promised students that I would destroy the tapes after I took notes on them, and this is what I did. Last year I attempted to interview a small group of students in the same room where 20 other children were working quietly. Since that situation created nervous giggles and lots of interruptions, this year I interviewed students privately, with no other students in the room. Students being interviewed brought their lunch to my room and ate it there. I offered cookies and fruit to them as a thank you.

Action research topics conducted by teachers are not the end. They are just a beginning step to understanding how students learn, and how to teach. This research project resulted in many opportunities to observe and collect data on the effects of using the 5E method of inquiry to teach. Although my methods were not all perfectly planned, or perfectly executed, learning did occur. The analysis of the data I collected follows.

DATA AND ANALYSIS

The methodology section described what I did. Now, it is time to look at the data I collected and what it means. First, I determined the baseline ability of my students by using the results of the standardized InViewTerraNova test.(CTB/McGraw Hill, 2011). This test gives the Cognitive Skills Index (CSI) for each student.

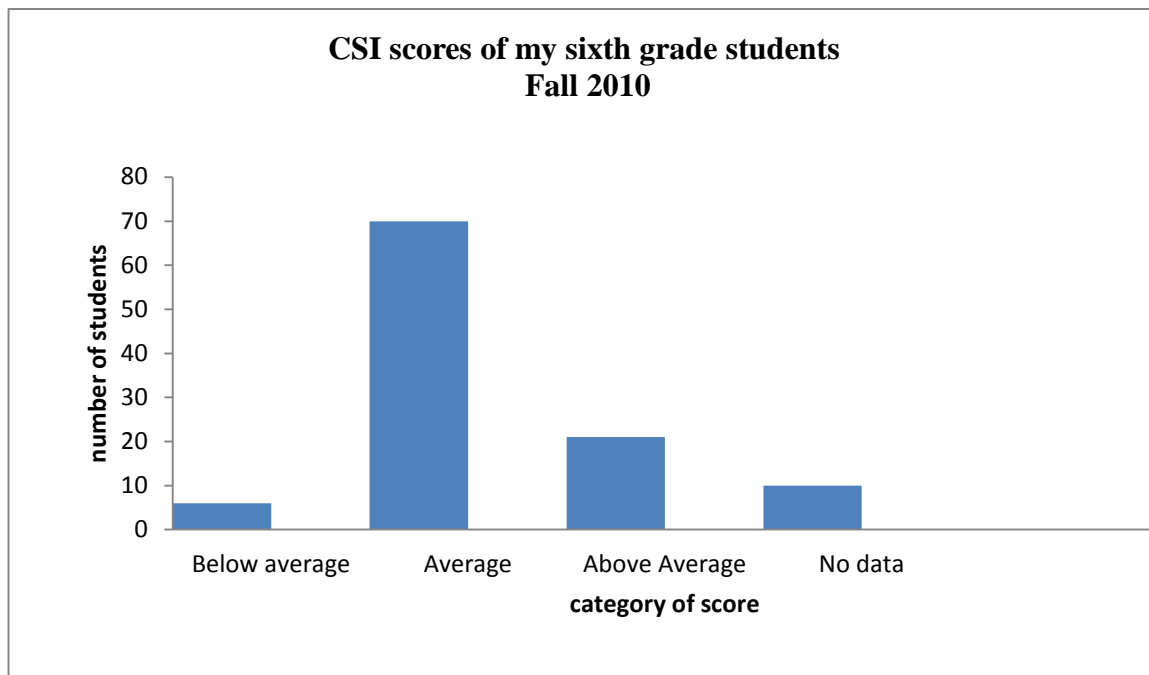


Figure 2. CSI (Cognitive Skills Index) of my sixth grade students, (CTB/McGraw Hill, 2011). ($N = 107$). Below average scores are below 84. Average scores are 84-116. Above average scores are 117 and above.

The largest number of students (70 students) in my group had scores in the normal CSI range. The number above average (21 students) is more than triple the number (6 students) of students below average. This tells me that students have the cognitive ability to do average or above average work for me. I do not need to factor in lack of ability when examining the results of my treatment.

Below are each of the questions that I am trying to answer followed by an analysis of the triangulated data that was collected.

Subquestion 1) What effect will inquiry methods have on their attitude towards learning science?

Figure 3, shows the results of a pre and post survey, and presents evidence that my students came to me with an overwhelmingly positive attitude towards learning science in school. Whatever “learning science in school” meant to them, they liked it! Enthusiasm is such a great attitude. From the survey I learned that my students expected that our time together in science would be a positive experience for them.

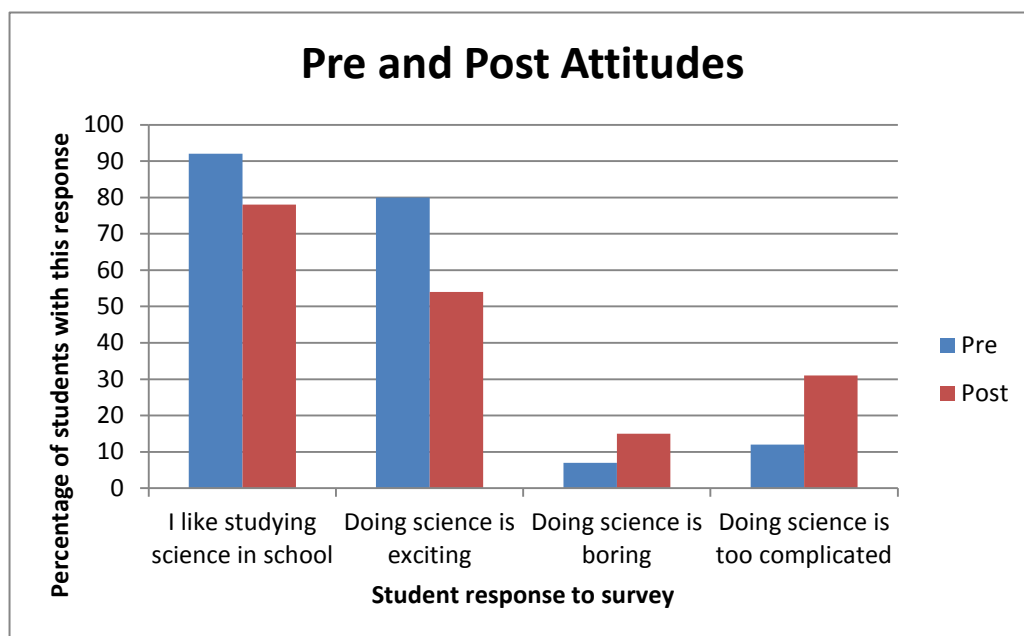


Figure 3. Student attitude towards learning science in school. $N=103$ on pretest and $N=89$ on post test.

The number of students who completed the post survey, “What do scientists do?” was only 85. One hundred three students completed the pre survey. Both times it was optional, and had nothing to do with their grades. In the pre-survey 93/103 (90%) of the students responded

yes to the question “Do you like studying science in school”. On the post survey, 70/89 students (79%) said yes to the same question. It is not an exact comparison, since 14 fewer students either chose not to respond, or did not make the time to do it. However, it is a sad statistic for me. Does it mean that they found out that science requires diligent, thoughtful and careful work, or were they bored out of their mind for ten weeks (while I was on medical leave) with substitutes who taught by reading aloud the textbook and assigning worksheets? I want to think that the latter is the reason. Evidence for this was very strongly voiced in the student interviews. All three interview groups (17 total students) lamented about how boring it was to just have the text read to them, and then to be assigned worksheets. They admitted that when I came back I made them work harder, but they were happy that they “never knew what to expect” from me, which made each day exciting. They agreed that it was much more fun to do experiments, to work in groups and to discuss the lessons. So if it was more fun to learn with inquiry, why did they have a drop in interest? Maybe it is just what happens at this transitional grade level.

I was encouraged when I read that indeed there is a honeymoon period in students’ attitude when they first begin learning by inquiry. Initially it seems great to them, until they realize that “the focus and responsibility of learning is on them, not the teacher”(Llewellyn, 2005.p. xiii). It is very common for student reaction to be insistence that the teacher tell them the right answer. Llewellyn also confirms that the level of student acceptance of inquiry will begin to go back up again after a period of time.

Sub question 2) What effect will inquiry methods have on their understanding of science concepts?

To determine the effect the treatment had on their understanding of science concepts, I compared my students' test scores on tests taught by the substitute while I was on medical leave with the test scores of the units I taught using the 5 E method. Figure 6 shows this comparison of inquiry units when compared to non-inquiry units that my students studied this year.

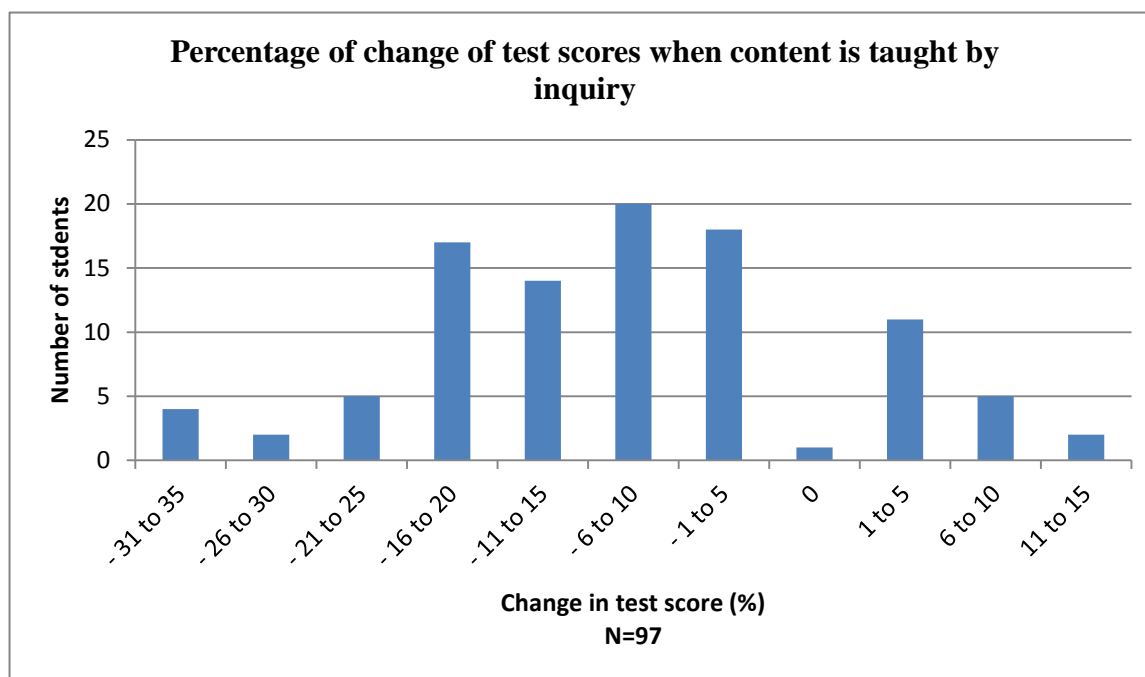


Figure 4. Percentage of change of test scores when content is taught by inquiry. Chart shows the number of students within each range of percentage. The change is compared to non-inquiry units, ($N=97$). Students who had higher scores on inquiry tests are to the right of zero. Lower scores on inquiry tests are shown to the left.

Only 19% of the students had better test scores on the inquiry units when compared to their scores on non-inquiry units. Seventy-five percent had lower test scores on the inquiry units. One student did not change. These are large differences in test scores, and it does not look good for the inquiry methods of teaching!

I looked at the item analysis of the magnetism and electricity test to see if I could discover a pattern. What I found is that questions dealing with concepts that students had

actively learned by experimentation had higher scores than those that dealt with vocabulary that simply had to be memorized. For example, 91% of the students correctly answered a question about electromagnets, and 97% correctly answered that magnets can push without touching. Identifying the vocabulary words, which was memorization was more difficult. Only 62% correctly identified a proton, 68% a neutron and 57% an electron. Forty eight percent correctly matched information about Michael Faraday and 58% could identify information about Thomas Davenport. If this unit had been taught with non-inquiry methods, perhaps more class review would have occurred with the vocabulary words, and they might have scored higher.

I also wonder if perhaps the scores were lower on inquiry units because students were unfamiliar with the methods, and having their sense of order changed left them unsure about what to study. The data that leads me to think this, but is not conclusive, is that the scores from the second unit of inquiry showed 37 students earned higher scores than the average of non-inquiry scores, and only 54 had lower scores. Four students had the same score on the second inquiry unit as their average on non-inquiry units. The second time, they got better. I predict that student scores on inquiry units would improve the longer inquiry methods were used. Studies noted in the literature review reported that student scores improve the longer that inquiry methods are used (Ruby, 2006). I think that the more confident students become with inquiry methods, the more their reasoning will improve and they will be able to better integrate information that has to be memorized with information they establish from experiments.

Comparing test scores is not the only data I looked at to determine their understanding of science concepts. I also looked at their responses to a survey called "What helps you learn?" It was a very short survey, shown in Figure 5 and described in the following paragraphs.

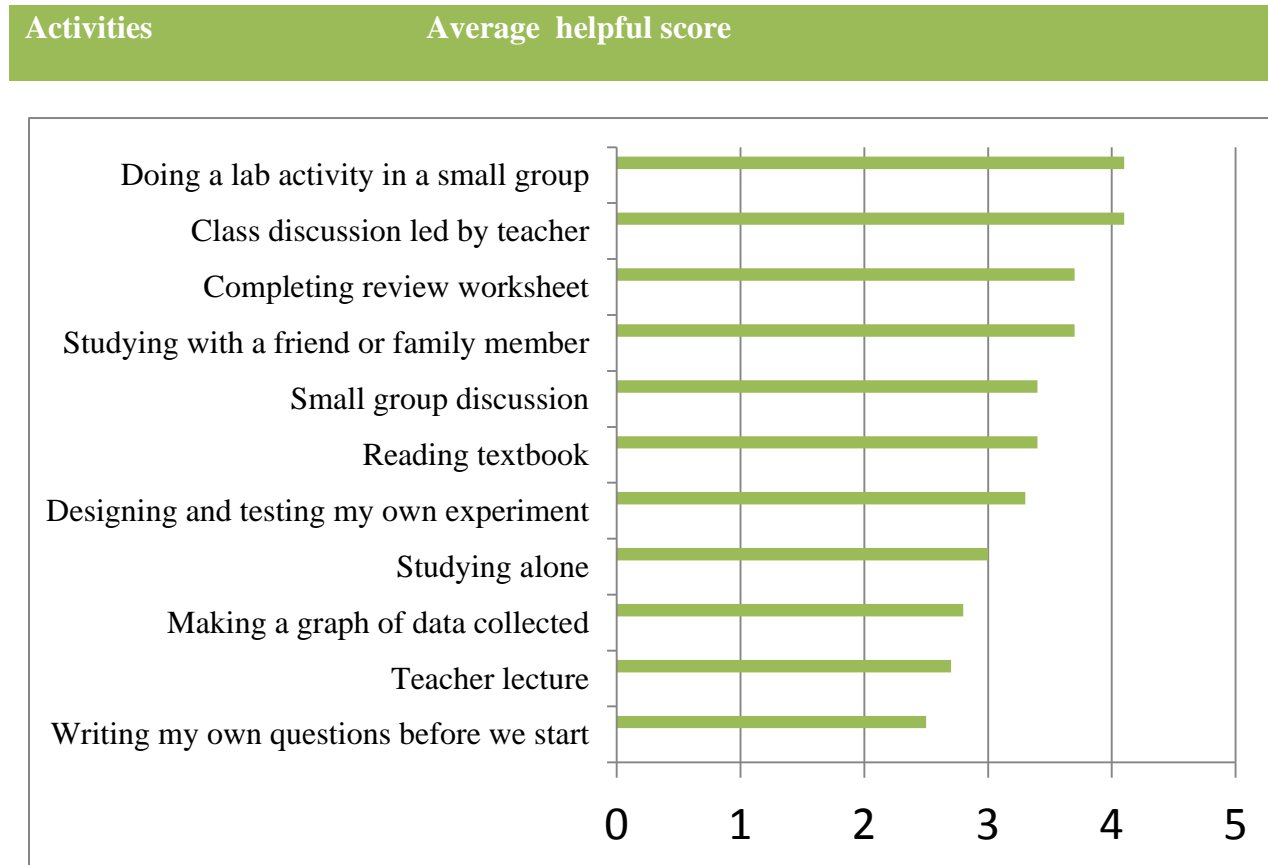


Figure 5.

What helps you learn? Results of Likert scale survey with 1 being a total waste of time. 2 being not helpful to me. 3 being undecided 4 being helpful to me 5 being extremely helpful to me. (N=97).

Asking students to write questions at the beginning of a new topic can be a way of engaging students. However, that activity from their viewpoint rates lowest of all items on the list! It is closely undesirable to making a graph, which is also a task that is helpful from a teacher point of view. The teacher lecture, which is a very unpopular and ineffective method of teaching actually ranks a bit higher than students writing their own questions. Why is this? I think one answer comes from their responses to the second part of the Likert scale.

The second part asked students to rank these terms according to how they described themselves. A response of one would mean 'not like me at all', three is 'undecided or neutral',

and a response of five would be 'this is definitely me'. Students claimed to be curious (4.2) and responsible (4.2) but hardworking only (3.8). This tells me that students in their hearts think that they probably are not working as hard as they could.

Student interviews were also valuable in answering this subquestion. An interesting comment came out in the student interviews. Sixth-graders felt like the textbook was too long and too involved. There were too many things to learn in each lesson and, "It is like trying to cram too many things into your head at once." They agreed that it was "better to learn slowly. You will get it stuck in your head and get it better."

What the student above was saying, and others agreed with is this: they want to learn, but sometimes there is too much to learn all at once, and their scores are lower because of the volume of information that has to be processed. When the substitutes taught the lessons, they were teaching information that had to be memorized. When I taught by inquiry, students were faced with information that they had to integrate into their own view of reality. Integrating concepts is a more difficult task!

Students were in agreement that the labs and experiments helped to "get it stuck in your head". Working in groups helped them to talk about what they were doing and figure out the best way to do things. Then when they shared their results to the class and answered classmates' questions, and compared their results to the results of their classmates, they learned even more. They were working like scientists and they felt both frustration and satisfaction. The following is a series of quotes from students in an interview group who built on what the previous student said. "You understand it better when you have both (reading and experiments). Experiments help you." "If you read the textbook first, then you like have hands on and learn more about it..." "Like you can read about it and then do the lab and then you get it."

Subquestion 3) What effect will inquiry methods have on the students' data collection and data organizational skills?

The Nature of Science test was my evaluation of what they knew about *doing* science at the beginning of the year. This unit helped define what questions science can answer and what it cannot. It explains the ways scientists work to be sure they have reached a true conclusion. They started off lacking in those skills, as determined by the Nature of Science test and by early performance tests requiring them to make a data table, record data, then take that data and graph it.

Figure 6 shows the results of the test on the Nature of Science (NOS) that was given at the beginning of the year. The chapter on the Nature of Science was given before the formal treatment, even though the material had been taught. It is a baseline pre-test. This test (Appendix H) was given to students again as a post test, after the two-unit treatment.

In the pre-test, the A and B grades together were scored by about a quarter of the students. Students with C grades make up a second quarter. The D range of grades was earned by over a quarter of the students. Students making an F on the test made up a smaller group than any group. The results were lower than I had expected. Note that in the data analysis, I found that the post tests on this chapter made no significant change. Although 45 students improved their scores, 45 students scores decreased, and seven stayed the same. The overall average for both pre and post tests was 71% and did not change even one percentage point! Data is nearly identical. My conclusion is that students entered sixth grade with minimal understanding of the nature of science and that teaching only two units using inquiry methods was not enough to change those scores. Understanding the nature of science, what science can do and what it cannot do, the definition and functions of laws and theories, the purpose of models and experiments, and

how information is gathered, tested and analyzed are difficult concepts that must be frequently revisited before students gain confident understanding of them. I would predict, based on the literature and my data in this research, that students would improve test scores on the Nature of Science test the longer inquiry methods were used.

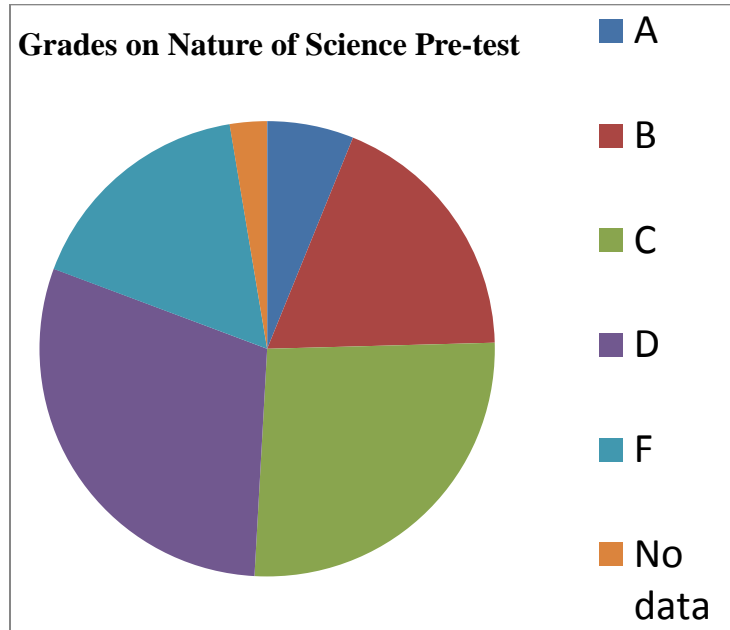


Figure 6. Results of Chapter One test – “The Nature of Science”, ($N= 107$) Grades labeled A are 90% - 100% correct, B= 80% - 89% correct, C= 70 – 79% correct, D= 60% - 69% correct. F = all grades 59% and below. No data means student did not take the test.

When students took the post-test, 45 students scored higher than they did originally and 45 students scored lower. Seven students had the same score on both the pre-test and post test of the NOS. The overall average of both the pre and post tests was 71% correct. That does not look like a gain or a loss for the group. The number of students who understand more clearly is matched by the number of students who are more confused! Some changes occurred among the students, but as a group they are just holding ground.

In trying to determine the baseline ability of my students to do science, a pattern that emerged as I looked at the survey (Appendix A) was that students were unfamiliar with variables

and controlled experiments. I was not expecting this eye-popping lack of experience doing science. See Figure 7 for what some questions on the original survey at the beginning of the year showed. I was expecting them to recite scientific methods as if they were a set of rules in order that all scientists followed. Instead, I discovered that they knew very little about scientific methods on any level. They had heard the terms and those who had been in a science fair could recognize some methods, but their idea of doing science was not locked into doing those certain things in a certain order every time. The literature that I read made me believe that students would have this inaccurate lock-step view of scientific methods, but that is not what I found. I don't see much data that documents they had any idea what doing science meant. It seems that they thought that smart people told learners about science and they memorized the facts and did some experiments to test them out safely.

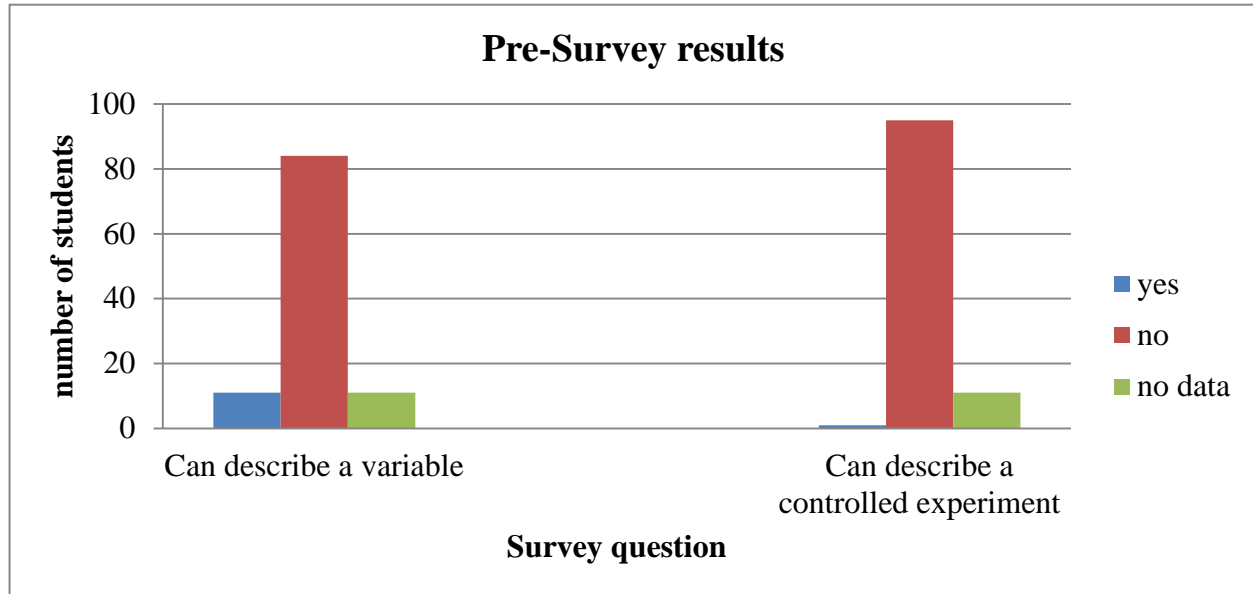


Figure 7. Results of survey questions, ($N=107$).

Only 103 students completed the survey, "What do scientists do?" (Appendix A). Seven students were special education students and the rest were general ed. students. The data for

Figure 7 comes from that survey. The information about identifying a controlled experiment and a variable came from what students wrote in typing boxes.

I asked many questions, but not all the questions I expected to be important were actually important! As I studied the results, I looked for patterns. What I saw was not what I expected.

Although 90% of the students who took the survey responded that they like studying science in school, none could describe a controlled experiment, and only 13 could describe a variable. The most common understanding of what a controlled experiment is had to do with safety issues. They thought a scientist should control the experiment so that no one would get hurt. None of them was able to say that a controlled experiment involves changing one factor and observing its effect on another while keeping all other factors constant. Since only thirteen of them knew what a variable is, being unable to describe a controlled experiment is understandable.

Performance tests were needed to determine if students have the skills of a scientist. One performance test that I gave asked students to take some simple data plus draw and complete a data table in the space provided, and draw and complete a line graph of the same information on provided graph paper. Few students were able to make a data table and enter data. The line graph presented more of a problem. Thirty seven students made bar graphs instead of line graphs.

As I analyzed this data, I reminded myself that I am working with 11 and 12 year old, sixth grade students. They have just come from elementary school, where the majority of time at school consists of an emphasis on learning to read and learning the addition/subtraction and multiplication/division facts and how to do basic math. Science class in some cases was limited to an exciting guest speaker with a wow presentation, a simple introductory lesson, a Bill Nye or

a Magic School Bus video. As I further analyze the data, it seems that students, although they want to learn science and think it is fun, do not come into sixth grade with skills for actually doing science.

So, they do not know the terms and they have little experience collecting, recording and analyzing data. They have some skills in reading tables and graphs, but are far from being competent in understanding where the data came from or how it was presented. They don't know how to design a table or graph, or how to title it. They may be infatuated with the idea of doing experiments but they do not actually realize that it might require discipline and careful attention to detail.

Questions in the survey, "What do scientists do?", helped me understand what students knew about what scientists do, if they could design a controlled experiment and what skills they believed they had in recording and organizing data. Before I reached my conclusion about these questions, I looked at several sources. Questions that stood out on the survey were helpful, as well as the results of the test on the nature of science. I had to combine data from the survey and from performance tests to establish the baseline of their skills. Student interviews helped to clarify other data.

Performance tests demonstrated repeatedly that students were unfamiliar and unskilled in making tables, collecting data and in graphing and analyzing results. In the student interviews, students said they got "confused if I have to make it myself, and that "... some people like me don't know how to set them up." They did not know what scale to use, how to make it, or what numbers to use. They preferred "taking notes" rather than collecting data in tables. They thought that they should be "working on them in middle school, but not graded on them until high school." They admitted that they had little experience with data tables and graphs in

elementary school. The consensus of this particular interview group was that students should be able to make and fill in tables and graphs by the first year of high school.

Another interview group confirmed that they had very little experience with data tables and graphs and were not sure about the difference at the beginning of the year. They had filled in some tables with information, but had not designed them or constructed their own at all in elementary school. And students said that lessons on graphs and data tables were limited to the chapters in the book that introduced them. When they finished the chapter, they were not mentioned again. It surprised them when I had them not only make them, but use them several times as we worked on experiments. In the interviews, students agreed that the data tables helped them organize the information in usable form and that graphs helped them “get a visual idea” of what the experiment showed. As one student said, “It is cool because you can see the change”. Another said, “ It helps you connect. And see it. The pattern.”

Here are the results of the pre and post performance tests for making tables and for making a line graph. Figure 8 shows the pre and post results for the table. Figure 9 shows the pre and post results for the line graph.

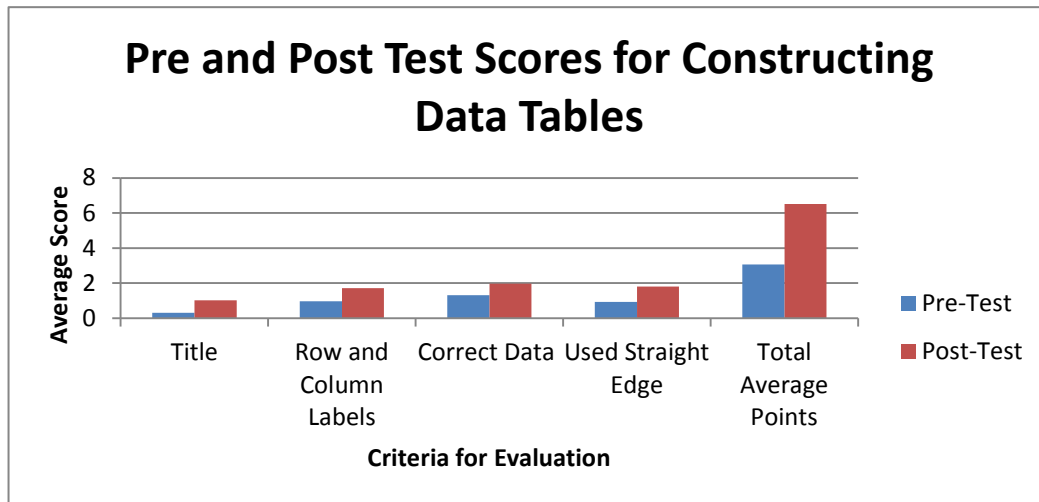


Figure 8. Pre and Post test scores for constructing data tables, ($N=76$). Two points were assigned for each criterion. A perfect total score is 8.

To help me understand their difficulties, I scored the tables on the criteria shown at the bottom of Figure 8. Then I averaged total scores. On the post tests students showed great gains in their ability to design a table and insert information. (The criteria for evaluating the line graphs is shown in Figure 9, and discussed next). Making a data table was extremely difficult for many students. The title seems to be the most neglected part of its construction. I understand that it requires a great deal of thinking to decide what information is being collected and how to make a place to record that information in a table. The title is often even harder for students to compose. Rows and columns are part of data tables, and labeling them simplifies the recording of data. To get both points, the title needed to include the age (time) and the unit (years or months). Part of the score included that they actually recorded the data in the table. This was the least of their troubles! Most of their experience with tables was in completing them with given data. My emphasis was on neat, orderly tables, and thus I required a ruler to make the lines. Many preferred to quickly freehand scribble a box of some sort.

A similar performance test was given after the treatments and the results are shown in

Figure 9.

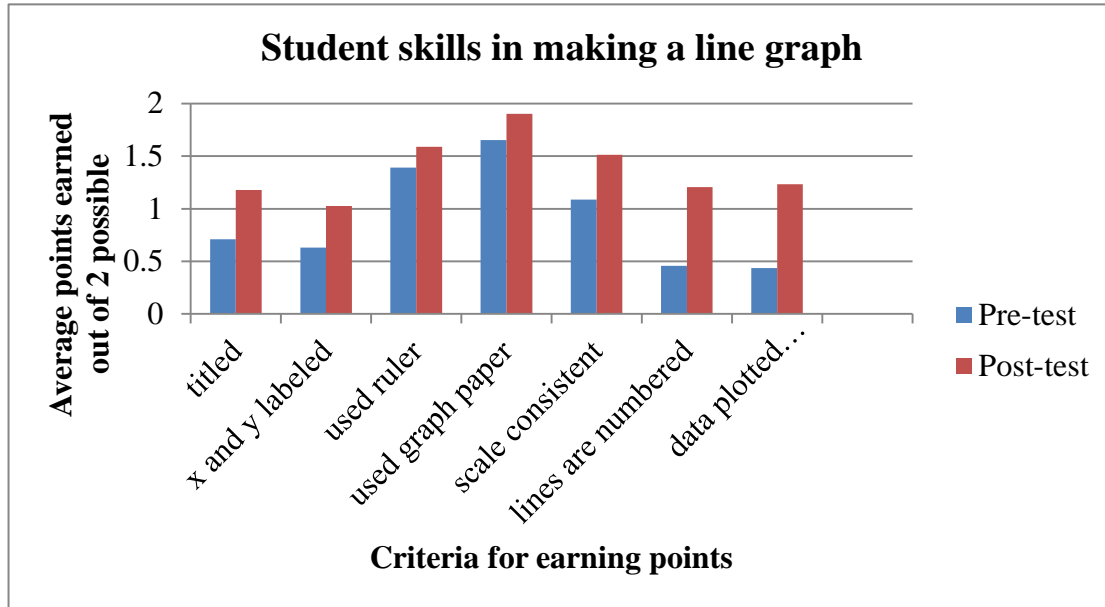


Figure 9. Pre and post test scores of performance test: Making a line graph, ($N=76$).

The post test for constructing tables and line graphs was done after both inquiry treatment units.

For the line graphs, I again gave a possible of two points for each criterion shown on Figure 9. A perfect score for the line graph would be 14 since there were seven criteria for this test. Thirty seven students made bar graphs instead of line graphs on the pre test. I was pleased to find out that only two students made a bar graph instead of a line graph on the post test. The results for the graphs are not quite valid for two of the criteria. I put graph paper and a ruler on each student's desk for both the pre and post tests and told students to use them. If instead, I had had a supply table for them to access, the results could have been much different. Not all math teachers require that students use graph paper and rulers to make graphs. Students come to us

from four elementary schools and had a number of different teachers with unknown expectations for making data tables and graphs.

In order to teach science using inquiry methods, students must be taught to design and complete data tables and to design and complete graphs. Because students collected data as they worked, and used graphs to help them see and communicate patterns, we used these tools often. Using them often made them familiar to students and they remembered what to do. Perhaps the first time you saddle a horse you need lots of help. But if you saddle your own horse every day before you ride, it isn't long before the task becomes easier. That is what using inquiry methods frequently will do for teaching students about data tables and graphs: the task will become easier.

Subquestion 4) What effect will inquiry methods have on students' ability to design and conduct a controlled experiment?

I discovered that students had not been given much opportunity at school to design experiments. I also discovered that they were not accustomed to taking ownership of finding answers to unanswered question that presented themselves in class.

In the interviews at the end of the year, I purposely chose to interview one group of students who were very high performing students. When I asked them if they wondered about the sinking ice cubes outside of class, they said that they did, but they did not try to solve the problem. One student said she did not have time, because "sports take up my time". The other students nodded at this comment. If they had assumed ownership of their own learning, as inquiry methods encourage, they would have continued the investigation outside of class.

I made some notes in my journal documenting what I heard students say on Day 2 of the first unit. They worked in groups that day to write a procedure to test one of the things they

thought caused wind. One of my perfectionists began to cry because she said she did not know where to begin. Two other high performers had researched the night before and brought with them a plan, which the little lambs in their group meekly followed. Some low students tried to distract their group with foolishness, or wander off to join another group. One low student did not say anything, but began flapping his book to make wind. They were allowed to use their textbooks, and many searched the books with a lost look on their faces. Others chatted with their books open and showed no evidence that they felt any pressure to figure something out. Two students who had made a reputation for themselves of not doing any work were put together as a pair, and actually got some real work done....that is, until the boy got his fingers stuck together with the girl's nail glue! One group decided that moving cars (and moving people) caused wind, so they had drawn a kid controlling a remote car. I asked them if that was enough movement for all the wind in the weather. One student said no, and led the group back to work some more, but one student held firmly to her idea. It amazed me how tightly they held on to their ideas. One of my top students sincerely believed that the earth's core heated the oceans and then that caused the weather. (I sat with his group a bit and questioned them about all the sources of heat for the earth. When someone suggested that the sun was a bigger source of heat for the surface, two in the group just hit themselves on the forehead, and said "duh!" and were ready to move on to another plan. Not the top student. He left the room arguing with them about how the heat from the earth's core was important in causing wind!

They turned in these papers as they left class because I wanted all the work done together at school, but the next day they presented their ideas to the class. They did not want to do this. In the first class, as I looked around the room I could see that they were very insecure. A boy mentioned that he felt stupid. With that I asked students if they thought scientists always figured

out something on the first try. They acknowledged that they probably did not. So then I asked them if they thought that scientists then just announced that they were stupid and gave up. Of course not! I reassured students that I thought they were smart and hard working and I was pleased with their efforts. They have good ideas; they are comparing them to what they already know to figure out what is true. It is my job to help them put those pieces together to reach an accurate understanding. That discourse relieved some of the tension. I began all the rest of the classes the same way. And I made a note to myself at this point in my journal. It is important for me to assure students that they are capable and that their efforts are pleasing me.

Discouragement does not yield good results. Somehow I have to convince them that their efforts are what matters, not immediate success each time. Isn't that a great life lesson?"

Student interviews in March revealed that my sixth graders were not used to figuring out scientific phenomena. They were used to having facts told to them, and perhaps having an opportunity to experience a lab that demonstrated the fact. Referring to the activity on the first day of school, where I presented students with two beakers of clear liquids containing ice cubes and asked them to try to explain why the ice cubes in one beaker floated but the ice cubes in the other beaker sunk to the bottom, students were still upset with me that I had not revealed the "correct" answer! Most had an idea or two, and some thought it might have something to do with density, but few had actually tested it. Most did not test it at home because they forgot about it, and some did not do it because their mom thought it would be messy. One student said that it was "not a good experiment because I never told them the answer". The group agreed. I asked if the only way they could learn is if I told them the answer. The consensus was yes, of course I needed to tell them the answer for them to learn. As one student said, "We could have

figured out something that worked but we never would have known if it was the right answer or not.” I see that as a lack of confidence in their personal ability to do science.

However, these same students said they liked going beyond just reading the textbook by working in groups and doing experiments in a group because “It makes us think Makes us work harder. You can try it and if it doesn’t work you can think of something else.” One student said:

“It makes you feel smarter when you work in a group because when you are in control of what you are doing and you are on your own it is a whole lot better and makes you feel smarter because you are making up your own ideas. And when you compare it, it doesn’t matter if they (other students in the group) are better but it makes you feel smarter because you came up with it yourself.”

There was great satisfaction in having their say, and having the opportunity to first think and then share in solving problems. For example, “I like it when everybody comes up with ideas individually first and then we put them together... with no one really controlling the experiment but with everyone giving their idea”. These are baby steps to solving problems in science.

Solving problems like scientists usually means working in groups. Working in collaborative groups has its own set of problems. These problems must be overcome in order for students to be successful in designing and conducting a controlled experiment with their peers. My students generally worked well together, and inquiry methods of teaching gave them more practice times than traditional methods of teaching. There is always room for improvement in ways of dealing with the personal dynamics of group work.

Here is one observation from my teacher journal of an activity involving group work and some resulting difficulties. I always anticipate that there will be students who do not work well

with others. One child in particular stood out this year though, when students were doing a lab activity. I had task cards for Recorder/Reporter, Principal Investigator, Time Keeper and Materials Manager. I left it to each group to decide who would be the best person to do each job. One particular student ended up with the job of Recorder/Reporter, but he wanted to be the Materials Manager. He complained to me, and I told him that he had to talk to his group and work it out. He went back to his group and tried to grab the card he wanted out of another student's hand! When the student with the card he wanted held on, he started crying and fussing at all of the others in the group. Before intervening, I watched from across the room. One student offered her job of Timekeeper, but he did not want it. He bawled and gritted his teeth. They looked at him warily. He came back to me and asked me if I could promise him that he would be the Materials Manager in the next group. I told him that he would be working with different people next time, and the group would need to decide together what job each person got. I asked the group to explain how they decided who would have each job. Their plan was not extremely fair, but it suited everyone except this one child. When he realized that no one would budge, he decided to take the Timekeeper job. ... Whew! This student was acting in accordance with his beliefs, as documented on his questionnaire. On the questionnaire, "What do Scientists Do?" he responded that he thought most scientists worked alone, and on the scale of importance of characteristics that scientists need to have, he rated being able to work alone as 4 out of 5 and ability to work in a group as 3 out of 5. This student has a CSI score of 134, so it is not a problem of not having the ability to reason. But he clearly does not understand the importance of scientists working together. By the end of the treatment time, I was pleased to see that he understood that he needed others to help solve problems. He had a number of meltdowns before he reached that decision, but his survey response changed to acknowledging that scientists

do work together and help each other. In one meltdown, he was hoarding all the materials that he and his competent partner needed to solve a problem, but was screaming at me to help him. The tears he shed were scary to his partner, but I kept directing him to let his partner see and touch the materials too, and to talk with the partner before I would help him. This one child did improve in his ability to get along with others as the number of times they worked in groups because he began to realize that he actually needed his peers to help him work, talk and solve problems.

More data was gathered that documents that students were unfamiliar with working like scientists. Early in the year, I gave students the task of figuring out how to get two pounds of beans from the floor to the top of the lab table using the least amount of effort. I showed them how a spring scale works and told them that we would measure with the spring scale. Their goal was to reduce the amount of effort by using a simple machine and spreading out the effort over distance. Together with my guidance they constructed a list of simple machines. I also put interactive sites on simple machines on their online course page.

(<http://www.cosi.org/files/Flash/simpMach/sm1.swf> and http://edheads.org/activities/simple-machines/frame_loader.htm). They were encouraged to learn about simple machines from these sites for homework.

Looking back at my journal of September 9th I noted some typically repeated actions. Students were obviously not accustomed to working together to solve problems. They were impulsive and did things just to be different, without planning or anticipating the outcomes. They investigated the pulleys and spring scales and timers and played with them and the yarn like toddlers with a new toy. There was a full range of engagement, from those who sat and looked at each other without talking, to the very serious problem solvers, to the completely laid-

back good-times kids. It was satisfying to see groups talking, problem- solving together and saying things like this statement that I overheard: “We need something to _____”. They were assigned jobs within the groups which most took seriously. However, some groups had dominant members who took over without considering the rest of the team. This prompted one girl who was grouped with three boys to say, “ Is there any group that needs me?” I laughed out loud when I read that journal entry in the spring! It is likely funnier to me because I remember the particular students, but the flavor of the day is evident.

My sixth graders were certainly not prepared for doing an experiment and finding out that they did not get the results they had expected. Failure is not something they have had to deal with. They had not yet designed an experiment, had it fail to give them answers, and had to do some critical thinking and brainstorming to figure out what to do next. They had not had to respectfully defend their ideas to others with strong opposite ideas.

The length of this study did not permit me to completely follow through with students successfully designing and conducting a controlled experiment by themselves. They did improve in their understanding of the purpose and definition of a controlled experiment. Using inquiry methods of teaching forced them to gain experience with the processes involved. The fact that they need to learn other skills and repeatedly practice using them is obvious from my observations , student interviews and the performance tests of my students.

Students have not had much experience solving problems, or using equipment. As stated earlier, the designing and conducting of a controlled experiment is something that can and should be done by sixth graders— but later in the year when their skills with the little steps have improved .

Subquestion 5) What effect will inquiry methods have on the teacher?

Teaching using inquiry methods affected me in several ways. Some that stand out are these: A) I had to allocate more calendar time to complete each unit. B) More teacher prep time was required. C) Additional lessons concerning skills and processes had to be taught. D) I felt a closer connection to my students. E).I had to adjust to the conditions of more activity and more noise in the classroom. F) I realized that I need to improve my skills of leading discussions without dominating them, giving formative assessments, guiding students to develop testable questions, allowing time for written student reflection, weaving in review of content and scientific vocabulary and in developing appropriate performance tests.

I expected inquiry teaching to require more teacher time, and more calendar time, and it did. Fifteen days for each unit is three school weeks. Most units take two weeks to do. For the teacher, extra time was required in planning and in teaching the smaller necessary steps. To begin each unit, I had to find an activity that would grab their attention and curiosity. I had to locate, incorporate, and design more student activities in my lesson plans. I could not just flip the teacher's manual open and begin a discussion of the text. Sometimes the lessons in the textbook were rearranged by me to be in a better sequence to follow the engagement activity. I found that student questions flowed in a different direction than the lessons were organized in the text. This is another example of extra planning time required.

Math teachers are not scheduled to teach tables, charts and graphs until April. Since students did not know how to construct these items, I had to include lessons to introduce, practice and evaluate them. The science book did not have adequate lessons to use in the support material, so I searched for these or constructed my own. The lessons required more days of class time.

When students considered what questions they had about the topic, I had to sort them to find similar questions and determine the questions that were testable in our situation. Then I found that since they knew so little about controlled experiments, I had to work with them as a class and model how to design a controlled experiment. To maintain the integrity of student work in designing the experiment, I chose to design a different experiment with each class. Then I typed up the experiments, and set up two stations for each lab. All classes tested all of the experiments. After the experiments were conducted, errors and weaknesses were found. Students worked with me to correct them, but I had to re-type the labs so students could test again.

Yes, it was a lot more work for me, but it was well worth it. I felt a closer connection to the students. As I looked through my journal entries I was reminded their eagerness and their vulnerability when they shared what they believed to be true. One student in particular had a knack for stating the obvious in question form. Sometimes others would laugh at her. Finally one day after they laughed, I reprimanded them by complimenting the child for her questions. I told them that she was *thinking* about the topic and trying to make sense of it and I was proud of her! That incident changed the students' perception of her questions and pleased her immensely! All the interaction with them alerted me to misconceptions that they had and challenged me to find ways to communicate and clear up the misconceptions. I was not just throwing out information. I was helping people examine their beliefs and challenging them to find the facts. Even though they could recite a statement from the textbook, it was not necessarily true that they believed it or even understood it. Often they had just memorized words and had only a vague idea of what they meant. Inquiry methods helped me to have a clearer perception of what they actually knew.

I found teaching this way to be sad at times, because students became frustrated. I encouraged them and praised their efforts. They got upset with me because I would not give them the right answer every time. I made them work for the answer. They felt stupid sometimes, though that was certainly not my intent.

And yes, it was noisier. Engaged students are more active and make more noise than politely quiet but disengaged ones. I can ride my mower all over the yard with the mower blade off, and it is a rather quiet ride. No grass gets cut, but the ride is quiet. Students whose bodies are there but whose minds are not are very quiet. Once the brains were engaged, the questions they asked me often surprised me, and possibly surprised them too!

As I look back on my project, I realize that I personally need more practice to effectively guide students to be inquirers. This work is just the beginning for me as I help to create the best learning environment for my students. I need to practice leading discussions without dominating them, giving formative assessments, guiding students to develop testable questions, allowing time for written student reflection, weaving in review of content and scientific vocabulary and developing appropriate performance tests. A prominent author of inquiry based instruction cautions teachers: “Don’t expect to become an inquiry-based teacher in just one year. Refining your skills and strategies takes time” (Llewellyn, 2005. p xiii). I have realized that teaching by inquiry requires being more in tune with students by listening carefully to them and teaching them how to communicate their observations and conclusions verbally and in writing. A researcher and a fourth grade science teacher shared what they learned about teaching explanation and the language of science to the students (Hodgson-Drysdale & Ballard, 2011). This teacher reinforced vocabulary development with a posted word bank which included the word, definition, and with a diagram if needed. I realize that I must facilitate the learning of

science vocabulary by allotting more time to learn, review and use these words. This will help students learn concepts and to enable them to discuss using scientific terms.

Overall, I am glad that I taught my students using the 5E method of inquiry. Initially it requires a lot of time and work, but I believe that in the long run, it is one of the successful strategies to use to teach our students how to be confident, accurate scientists.

INTERPRETATION AND CONCLUSION

As a final summation of what I learned from this research, I go back to my original questions. Data from this research documented on surveys that students were less interested in learning science in school, because it was boring, or too complicated (Figure 3). However, with me on medical leave, students had more than one whole grading period with substitutes who taught using non-inquiry methods. All of the students interviewed made comments about how boring that was for them. They also were all very interested in exploring science with inquiry methods.

Test scores showed that students did not improve in their understanding of concepts when inquiry methods were used (Figure 4). The nature of science pre and post tests did not document any other change either. However, I am holding out for test scores to improve as inquiry skills improve, as noted by research in these articles and others in the literature review (Blanchare, Southerland, Osborne, Sampson, & Granger, 2010; (Llewellen, 2005)Lowery, 2010; Ruby 2006; Liftig, 2010; Brown et al., 2009).

Figures 8 and 9 document that data collection and organizational skills greatly improved and student interviews confirmed that students not only felt more confident making and using

tables and graphs, but they also appreciated how they helped them visualize the data. Before the treatment, I found students to be unfamiliar with variables and designing experiments. They continued to make a bar graph when told to make a line graph, even when I emphasized very strongly that they should make line graphs because we were documenting change over time. They were unfamiliar with making and using tables, and had to be taught and re-taught how to do these things. They were usually able to read graphs satisfactorily, but did not know how to decide on an appropriate title, set the scale or plot information when they made their own graphs.

In the beginning, on the pre-survey, less than 10% of my students could identify a variable and none could even define a controlled experiment (Figure 6). On the post survey, 45% of them were able to identify a variable and 32% could define a controlled experiment. They brainstormed questions and how to test them, and as a class with my direction, designed and conducted a controlled experiment. These are baby steps, but they are improvement.

As my teacher journal documented, and my reflections of these and the data indicate I am excited about using inquiry methods. I believe that the extra work that I did is worth the time I put into it. I received an unsolicited email from the parent of a high-achieving student which was one more reason I found inquiry methods successful. This letter expressed feelings that I expected students to experience when inquiry methods are used. The mother wrote to me “There was little, if no, problem solving last year at (elementary school). No science experiments, just pure regurgitation of material in science and math. (Student) can spit out an answer with no problem. But, to have to use her brain ... well that is another story.

VALUE

Teaching by inquiry means that students will be actively involved in the formulation of questions, the designing of experiments and in drawing conclusions. Students who expected to be given a list of information to learn for the test were startled, and reacted in different ways.

The inquiry methods that I was able to introduce before I left for medical leave yielded some interesting data. The example of the student in the previous narrative, not being willing to work with others is one example. The frustration level students experienced when trying to design an apparatus using a simple machine that would lift a two pound bag of beans to the tabletop is another. In my journal I noted that students were unaccustomed to having to design something together.

It is not enough to learn scientific facts. If we are to take this “Sputnik moment” that President Obama sees in improving science education, students must learn the ways scientists work to discover and identify facts, theories and laws. I hoped that using inquiry methods of teaching would encourage my students to be curious and develop the skills to ask questions and seek answers with confidence. I was successful in starting that ball rolling. Other teachers will need to continue giving students the opportunity to use those skills. No one would expect a person to become an expert knitter by simply watching videos and learning terms. A knitter needs to practice, practice, and practice! They will make mistakes and they will learn from their mistakes if they are given the opportunity to practice.

Did my sixth graders see inquiry as a comfortable yet challenging way of learning science? Challenging, yes, but comfortable, no. Not yet. It made some of them feel stupid or panicked because they were not familiar with how to solve problems. I began this research to

learn how using inquiry methods to teach science would affect me and my students. The short answer to that is that it opened my eyes to what students really aren't learning when we just "go over" a unit, and it opened my students' eyes to the wonder and frustrations of working like real scientists. This previous sentence is the apex of what I learned from this research.

What suggestions did they have for me, as I continue to teach science to sixth graders? Students pointed out to me in surveys and interviews how important that review is to the learning process. They commented that they learned more about tables and graphs this year because we kept using them. They encouraged me to include review questions from previous chapters as part of or as bonus questions in the next chapter. They said they don't get things the first time and want to keep doing labs until they know how to use the equipment properly and make their own tables and graphs. Some of my top students suggested that I give pop quizzes about past learning so that they don't forget the material.

Students are not just empty buckets where we dump information. They are people who have developed ideas about reality, whether they are conscious of these ideas or not.

Until I took the class at Montana State University on teaching science using inquiry methods, I knew very little about these strategies. Now, I have some experience using the 5E method of inquiry. I have seen how it both frustrates students and challenges them. I have learned that their science content scores will improve eventually, but may drop initially until students become skilled in working like scientists. My students have shared with me suggestions that will help me to strengthen the learning with frequent review and opportunities to use what they have learned. They have suggested that I structure groups to include both boys and girls so that it will be fun as well as productive when they do experiments. Students said that groups with all boys often got loud, silly and off task and that groups with all girls was either too serious

or off task talking. They thought working in groups with mixed gender was a more productive yet fun group, and I agree with them.

It is both pleasing and exciting to me to know that the new middle school science textbook our corporation has adopted beginning next year, is a textbook that is written using the 5E method as scaffolding! All six of the middle schools in our corporation will use this textbook for the next five years. The new textbook will provide additional help to me as I continue to use the 5E method of inquiry to teach my students. Camaraderie with other teachers using the same methods will help me to refine my skills. I will also have the satisfaction of knowing that on some level, what I have taught my sixth graders this year will be reinforced for the next two years in their middle school educational experience.

Based on my research, here are some recommendations for other teachers who have never attempted to use inquiry methods. Expect it to take more time. Students come to you with preconceived ideas. They do not want to give these up. They must face the evidence, and be allowed to challenge that evidence in various ways before they finally accept new ideas. Some students have never really thought about science before. They may have been taught interesting facts, and they may have dutifully memorized information but sixth graders often have little experience doing science. They have been wowed with demonstrations, perhaps, but this grade level is where they first begin to learn the self-discipline needed to carefully make and record observations in an organized table. They are just learning about reading graphs, and will need practice designing and finishing them. You can “slop the hogs”-- i.e. “cover the material” much quicker than students can digest and integrate the information into understanding. They can memorize quicker than they can learn. Provide plenty of opportunity and time for them to practice the little steps of doing science.

The National Science Teachers' Association (NSTA) publication, *Science & Children* is dedicated to "A year of inquiry" in 2011. Articles in many of the 2011 publications offer suggestions for changing cookbook labs to open inquiry, (Lott; Bergman & Olson; Magee & Flessner; Owens & Martin, 2011) investigations to become student-directed inquiry, (Joseph, 2011) and lessons to enable students to create their own investigations (Morgan and Ansberry; Lynch & Zencbak 2011). One article claims to embrace the tensions in teaching inquiry-based science (Weller and Finkelstein, 2011). Even the editorials (Bybee; Froschauer, 2011) note the importance of inquiry methods in teaching science and the challenges that teachers face in attempting this. Formative assessment is needed to understand student conceptions and misconceptions (Keeley, 2011). So, we understand that using inquiry methods to teach requires new skills on the part of the teacher. And teachers, as well as students, need to take baby steps to reach the goals of implementing successful inquiry methods in the science classrooms of our nation.

Students do not naturally document their observations with words or drawings. They need help to express themselves as they discuss what they observed and what they concluded from their work. They need practice discussing using scientific thinking and purposeful reflection. One researcher collaborated with a fifth-grade teacher to help his students make sense of their data by teaching them to think in terms of claims, evidence and reasoning (McNeill & Martin, 2011). They need to organize the whole process with written documentation and revisit what they have written (Froschauer; Ashbrook, 2011). Teacher guidance and encouragement in all these areas is very important.

I look forward to the time this fall when I will have a student teacher, because communication with her has revealed that she has learned inquiry methods in her undergraduate

work. Combining that experience with her former career of a nurse, and my experience and what I have learned from my research, leads me to anticipate a great time of collaborative learning for both teachers and students.

Inquiry is only one of many effective strategies that teachers use to teach science. It is not a cure all. It is simply a way to involve students in the process of doing science. In any area of study, there are times for memorization and review. However, without allowing students to get involved in the work, and requiring them to think and reason and choose and analyze, they will attain only surface learning.

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APPENDICES

APPENDIX A

SURVEY – WHAT DO SCIENTISTS DO?

What do scientists do?

* 1 What is today's date?

Use the month/day/year format, e.g. for March 14th, 1945: **3/14/1945**

* 2 I am a

boy
 girl

* 3 Do you like studying science in school?

Yes No

* 4 I believe that most scientists work

* 5 I believe that doing scientific research is

* 6 I believe that the space program

* 7 Good scientists can believe in God.

Yes No

- *
8 Which qualities are important for scientists? Rank each one on a scale of 1- 5. If you mark 5 that means you think it is very important. Marking a 1 means not important or true at all.

	1	2	3	4	5
keeps trying something else if an idea does not work	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
stops doing something when it gets hard	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
curious	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
creative	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
able to work alone	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
able to work in a group	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
measures exactly	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
guesses when recording time, mass, temperature, distance etc.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
keeps information in a table or graph	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
jots information on scraps of paper or simply remembers it	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

- *
9 Which of these questions can science answer? Mark 2 if the question can be answered by science. Mark 1 if the question cannot be answered by science.

	1	2
how far it is to the moon	<input type="radio"/>	<input type="radio"/>
the temperature changes occurring in a certain city for a year	<input type="radio"/>	<input type="radio"/>
if a planet has water	<input type="radio"/>	<input type="radio"/>
who is the best candidate for President of the United States	<input type="radio"/>	<input type="radio"/>
who is the prettiest girl in the class	<input type="radio"/>	<input type="radio"/>
the existence of God	<input type="radio"/>	<input type="radio"/>
the structure of a cell	<input type="radio"/>	<input type="radio"/>

how sound travels



the intelligence of an animal



10 * I think that an invention is USUALLY the result of

Choose...

11 * How would you describe what scientists do? List as many action words as you can.

12 * Describe the scientific method. What things are done? Is there an order to it? (if so, tell the sequence). Do all scientists follow this?

13 * Give some examples of models that scientists have made. Why were these models important? What problems might using a model cause?

* What are some things you would do if you needed to know what was in a box, but could not open or damage the box?

14

15*

How would you rate each of these science topics? If you mark a 5 that means you think it is very interesting. A one means it is not interesting to you at all.

	1	2	3	4	5
chemisty	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
forestry	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
insects	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
volcanoes	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
planets	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
things in motion	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
soil	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
bacteria	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
viruses	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
gravity	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
machines	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
how electronic items work	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
plants	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
animals	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
rocks	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

16

What does "controlled experiment" mean? What is the importance or this kind of experiment?



17 * In an experiment, what is a variable?



18 * What is the difference in a scientific law and a scientific theory?



19 * If someone claimed that they had scientifically proved something, what would you want to check before you believed them?



APPENDIX B

SURVEY – WHAT ABOUT SCIENCE FAIRS?

What about Science Fairs?

* 1 What is TODAY's date?

Use the month/day/year format, e.g. for March 14th, 1945: **3/14/1945**

* 2 Have you ever done a Science Fair project?

Yes No

* 3 If you have entered a science fair, what was the question you studied? (If you have entered more than once, please share all the topics.)

If you have never been in a science fair, tell me why you have not done that.

* 4 What are some things you wonder about?

* 5 What IF you could read peoples' minds?

What IF you could visit your grandma in California by being "beamed" there?

What IF students had to provide all the electricity needed by their school, by riding stationary bikes that generated electricity?

Now YOU write three more "What IF" s. Be creative!



- 6** * What is the tiniest thing you have ever looked at that you did not use a magnifying glass or microscope to see?



- 7** * If a tree falls in a forest, and no one is there to hear it fall, does it still make a loud sound? Explain.



APPENDIX C

DESIGN AN EXPERIMENT TEMPLATE

Design an Experiment

What question do you want to answer? _____

What are some variables that must be kept **constant** in order for the test to be fair and be a controlled experiment? _____

What one variable will change in this experiment? (This is the **independent variable**)

What variable will change as a result of the change in the independent variable? (This is the **dependent variable**.)

List the materials you will need to do this experiment. _____

Write the steps, in order, that you will do in this experiment.

1. _____

2. _____

3. _____

(If you have more steps than this, write them on a piece of notebook paper and attach to this paper.)

What safety precautions should you take when doing this experiment? _____

Use a ruler to draw a data table where you will record the changes in the dependent variable. Draw this on another sheet of paper and attach to this paper.

Prepare a graph of your results. This will help you communicate your findings with others. Write the names of all of the people in your group. _____

APPENDIX D

ATMOSPHERE TEST

Preview TEST - chapter 3 - The Earth's atmosphere

5934

1

Start again

Note: This quiz is not currently available to your students

Question 1 

Marks: 1

Some students conducted an experiment to test the heating and cooling rates of land and water. Which of the following was determined to be true?

Choose one answer.

- a. land and water heat and cool at the same rate
- b. land heats and cools faster than water
- c. water heats and cools faster than land
- d. land heats faster, but water cools faster

Question 2 

Marks: 1

Some students conducted an experiment to see why different latitudes on earth receive different amounts of the sun's radiation. Which of these latitudes received the least heat from the sun?

Choose one answer.

- a. 0 degrees latitude
- b. 90 degrees north and south latitude
- c. 45 degrees north and south latitude

Question 3 

Marks: 4

Identify the process that occurs in each case.

water changes from frozen ice at the poles to water vapor, skipping the liquid state

Choose... 

water changes to a gas

Choose... 

water falls out of the sky as rain

Choose... 

water vapor changes to a liquid

Choose... 

Question 4 

Marks: 6

Match the names of the winds with the description.

Which surface winds are responsible for most of the weather movement across the United States?

Choose... 

What are narrow belts of strong winds near the top of the troposphere called?

Cold winds coming from the poles.

Local winds caused by the fact that land heats up faster and cools off slower than water.

Early sailors used these winds to travel the global trade routes.

The area near the equator where there is little or no wind

Question 5 

Marks: 1

In class, some groups of students conducted an experiment involving ice and salt in beakers. This was a controlled experiment. In this experiment, identify each of the parts of a controlled experiment

the temperature changes

the same amount of ice in each beaker

the amount of salt in each beaker

Question 6 

Marks: 1

Hot air rises and moves in a current directly above the land. Why then do global winds appear to curve?

Choose one answer.

- a. radiation
- b. jet stream
- c. the Coriolis effect
- d. convection

Question 7 

Marks: 5

Identify the way that energy is transferred in each case. Answers may be used more than once.

Energy is transferred in a room as hot air rises and cold air sinks

water in a pan on the stove gets hot and moves to the top, while colder water sinks to the bottom of the pan

You can warm yourself by a fire because the heat is transferred this way.

energy travels from the Sun through empty space in this way

a pan on a stove gets hot because it is touching a hot burner.

Choose... ▼

Question 8 🚩

Marks: 1

Some of the Sun's energy is reflected and sent back into space by the Earth's atmosphere and clouds before it ever reaches the surface.

Answer:

- True False

Question 9 🚩

Marks: 1

Why does the moon have so many craters?

Choose one answer.

- a. The craters are the result of old volcanic activity.
- b. It has no atmosphere which could burn up meteors before they hit the surface of the moon.
- c. There are more meteors close to the moon.
- d. The gravity on the moon is very strong and it pulls meteors to it.

Question 10 🚩

Marks: 1

Which of these is NOT a cause of air pressure?

Choose one answer.

- a. the chemical interaction between nitrogen and oxygen
- b. the temperature of the air molecules
- c. the number of air molecules present

Question 11 🚩

Marks: 1

Nitrogen makes up what percentage of the atmosphere?

Choose one answer.

- a. 21%
- b. 78%
- c. 90%
- d. 1%

Question 12 

Marks: 1

Which of these does NOT affect the amount of energy the Earth receives from the Sun?
Choose one answer.

- a. the clouds
- b. Earth's atmosphere
- c. the moon
- d. the ozone layer

Question 13 

Marks: 5

Choose the vocabulary words that best fit in each blank.

Heat energy transferred in the form of waves is called ____.

The thin layer of air that surrounds Earth is called the ____.

Chloroflourocarbons are dangerous because they destroy the ____.

The ozone layer helps protects us from ____.

Narrow belts of strong winds called _____ blow near the top of the troposphere.

Question 14 

Marks: 1

It is important to life on Earth, that all the energy from the Sun reaches the surface of the Earth.

Answer:

- True
- False

Question 15 

Marks: 1

Identify each of the parts of a controlled experiment.

the result of changing the independent variable

the one variable that is changed

something that can change

a variable that has been controlled to make the test fair

Question 16 

Marks: 8

Match the fact with the layer of the atmosphere. An answer may be used more than once.

Which layer protects living things from too much ultraviolet radiation?

Choose... ▼

The ozone layer is found in this layer.

Choose... ▼

Which layer has the most water?

Choose... ▼

This layer reflects radio waves. It is located partially in the mesosphere and partially in the thermosphere.

Choose... ▼

Which is the uppermost layer of the atmosphere?

Choose... ▼

This is the hottest layer of the atmosphere (and also the coldest!)

Choose... ▼

Where is air pressure least?

Choose... ▼

Most meteors burn up in this layer

Choose... ▼

Question 17 

Marks: 1

The energy to power the water cycle comes from _____.
Choose one answer.

- a. the rotation of the Earth
- b. the tilt of the Earth on its axis
- c. the Sun
- d. the moon

Save without submitting

Submit all and finish

0

87263,87264,857



APPENDIX E

SURVEY – WHAT HELPS YOU LEARN?

What helps you learn?

Please answer these questions honestly. There are no right or wrong answers, only your opinions. Be serious in your choices, since these will help me to be a better teacher.

* What activities help YOU learn better? Rank these activities based on how they

1 affect your learning.

Answer these questions using this scale.

1 means it is a total waste of time 2 means this is not helpful to you 3 means you are undecided 4 means it is helpful to you 5 means it is extremely helpful to you

Rate these tasks according to how they help you learn.

	1	2	3	4	5
Reading the textbook	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Writing answers to questions at the end of the lesson	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Completing a review worksheet	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Doing a lab activity in a small group	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Studying alone	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Studying with a friend or family member	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Teacher lecture	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Class discussion led by teacher	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Small group discussion	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Writing my own questions about a topic before we start the chapter	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Designing and testing my own experiment, alone or with one or more friends	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Making a graph of the data collected in an experiment	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Figuring out how to solve a problem with materials in my hand	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Watching a video	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

2 Which of these qualities describe you best? Choose an answer for each question.

1 means definitely not me 2 means not very true for me 3 means undecided 4 means this is somewhat like me 5 means this is definitely me

	1	2	3	4	5
Curious	●	●	●	●	●
Hard working	●	●	●	●	●
Responsible	●	●	●	●	●

 Moodle Docs for this page

APPENDIX F

MAGNET ACTIVITY SHEET

Magnet Activity Sheet.

Your name _____ date _____ class period _____

Use the circular magnets to test, and write the results on this paper. Paper is due at the end of the period.

1. Test the magnets on these items (if available) and other items at your desk that belong to you. ... Pencil, rings on binder, dime, penny, quarter, nickel, paper, folder, clothes, paper clip, pop can or pop top, metal on ink pen, ink pen, plastic ruler, hair

List **at least three** things that the magnets are attracted to. _____

List **at least three things** that the magnets are NOT attracted to. _____

2. Test these and other items that belong to you at your desk to see if the magnets are attracted to each other **through** these items. Use items listed above, plus ear lobe, desk, etc.

List **at least three things** that the magnets are attracted to each other **through**. _____

List **at least three things** that the magnets are NOT attracted to each other **through**. _____

3. Make one magnet move by touching it with the other magnet. Then make one magnet move using the other magnet, but not touching the magnets together. Describe what happened. _____

4. Make one magnet **spin** by using the other magnet, but **not touching** the magnets together. Describe what you did and what happened. Draw a picture in the margin of this paper.

Other comments about these activities _____

APPENDIX G

ELECTRICITY AND MAGNETISM TEST

Preview TEST - Electricity and Magnetism

6221

1

Start again

Note: This quiz is not currently available to your students

Question 1 

Marks: 1

The Earth has a magnetic field around it.

Answer:


True False

Question 2 


Marks: 4

What am I?


I can pick up magnetic materials as long as an electric current is passing through my coils

Choose... 


I build up as you walk across a carpeted floor

Choose... 

I can change mechanical energy into electric energy

Choose... 

I am an electric discharge


Choose... 

Question 3 


Marks: 1

Identify the kind of electric circuit.

has more than one path that electric current can follow

Choose... 

has only one path that electric current can follow

Choose... 

Question 4 

Marks: 1

If a circuit has a voltage of 15 volts and a current of 0.25 amps, what is the resistance in Ohms? Hint: $V = I \times R$ (type only the number of your answer).

Answer:

Question 5 

Marks: 1

Batteries have positive and negative poles.

Answer:

True False

Question 6 

Marks: 6

Match the terms and definitions.

a very large magnet

Choose... 

the rearrangement of an electric charge due to the presence of an electrical field

Choose... 

a device that converts mechanical energy into electrical energy by moving a magnet and a wire loop relative to each other

Choose... 

copper, aluminum, iron

Choose... 

electrically charging another object when objects touch each other

Choose... 

plastics, glass, rubber, wood

Choose... Question 7 

Marks: 1

Which of the following does NOT describe the magnetic force between two magnets?
Choose one answer.

- a. it decreases as the magnets move apart.
- b. unlike poles attract
- c. like poles attract
- d. like poles repel

Question 8 

Marks: 1

Who am I?

I made the first electric generator, and am considered the Father of Electricity.

Choose... 

I decided that if mechanical energy could be used to make electricity, then electricity could be used to make mechanical energy. I made the first electric motor, and other inventions.

Choose... Question 9 

Marks: 1

An electromagnet is a type of
Choose one answer.

- parallel circuit
- temporary magnet

- generator
- permanent magnet

Question 10 

Marks: 1

What does a simple generator rotate in a magnetic field to produce an electric current?
Choose one answer.

- a. a wire loop
- b. domains
- c. a battery
- d. a magnet

Question 11 

Marks: 1

Only metals that contain these elements are attracted to magnets.
Choose one answer.

- a. aluminum, nickel, iron and rare earth elements like neodymium
- b. iron, nickel, cobalt and a few rare earth elements like neodymium
- c. aluminum, nickel, neodymium and iron
- d. copper, iron, steel and nickel

Question 12 

Marks: 1

Magnets can push each other without touching each other.

Answer:

- True
- False

Question 13 

Marks: 5

Match the terms and descriptions.

the flow of electric charges

Choose... 

the process of providing a path to drain excess electrical charge into the earth.

Choose... 

the movement of static charge from one object to another

Choose... 

a closed path in which electric charges can flow

Choose... 

the imbalance of electric charge on an object

Choose... 

Question 14 

Marks: 1

Which of the following is true about a permanent magnet?

Choose one answer.

- a. it contains an iron core
- b. its domains are randomly oriented
- c. It contains a current-carrying wire
- d. its domains are lined up

Question 15 

Marks: 1

A compass needle points north because ____.

Choose one answer.

- it contains an electrolyte
- it runs on electricity.
- it is connected to a GPS signal.
- the Earth is surrounded by a magnetic field.

Question 16 

Marks: 1

If one object has a positive charge and one object has a negative charge, they __ each other.

Choose one answer.

- a. attract
- b. don't affect
- c. repel
- d. explode

Question 17 


Marks: 5

Match the terms and the definitions.

parts of an atom that has no charge

Choose... 

materials with electrons held loosely by the atoms so that electrons can move through the material easily. Electric charges move easily through

Choose... 

the material

parts of an atom with a positive charge

Choose... ▼

materials with electrons held tightly by the atoms. Electrical charges canNOT move through these materials easily.

Choose... ▼

parts of an atom with a negative charge

Choose... ▼

Question 18 🚩

Marks: 1

Ohm's Law expresses the relationship of
Choose one answer.

- voltage, current, and resistance
- series and parallel circuits
- electric charge and magnetic field
- voltage, current, and electric discharge

Question 19 🚩

Marks: 1

The electric field surrounding an electric charge _____.
Choose one answer.

- a. is invisible
- b. can be seen with a powerful microscope
- c. can be easily seen
- d. is blue

Question 20 🚩

Marks: 1

Like poles of a magnet ____ each other.

Choose one answer.

- a. explode
- b. attract
- c. repel
- d. don't affect

Question 21 🚩

Marks: 1

Which of these arrangements would produce the most voltage? (..and make a single bulb brighter than a single bulb powered by a single battery)

Choose one answer.

- connecting the positive end of one battery to the positive end of another battery
- batteries arranged end to end (in series)
- batteries arranged side by side (parallel)
- the arrangement of batteries has no effect on the voltage

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APPENDIX H

CHAPTER ONE TEST – NATURE OF SCIENCE – PRE AND POST TEST

Preview chapter 1 test

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Students will see this quiz in a secure window
Note: This quiz is not currently available to your students

Question 1 

Marks: 1

Check ALL that are part of a good data table.
Choose at least one answer.

- accurate data
- drawn free hand
- labeled columns
- labeled rows
- title
- has a horizontal axis
- has a vertical axis
- drawn with a ruler

Question 2 

Marks: 1

A camera is an example of ____.
Choose one answer.

- a. a model
- b. technology
- c. a robot
- d. an experiment

Question 3 

Marks: 1

What are three basic types of models that scientists use? Choose three answers.

Choose at least one answer.

- a. mathematical model
- b. weather model
- c. physical model
- d. computer model
- e. idea model


f. paper model

Question 4 


Marks: 1

Match the definitions with the correct words.

a good way to organize your observations

Choose... 

to see, hear or gather information with your senses.

Choose... 

to draw a conclusion based on what you see, notice or hear

Choose... 

Question 5 

Marks: 1

The job of physical therapist would fit into which branch of science?

Choose one answer.

- a. Physical Science
- b. Earth Science
- c. Life Science

Question 6 

Marks: 1

Match these terms to their meanings.

involves changing one factor and observing its effect on another while keeping all other factors constant.

Choose... 

factors that can be changed in an experiment

Choose... 

thoughtful consideration of the results of tests or experiments

Choose... 

Question 7 

Marks: 1

Scientists are very careful to follow safety procedures. In this class when we do labs, the instructions will have safety symbols listed. What will you do when you see the symbols?

Choose one answer.

- a. Follow the precautions indicated by the picture.
- b. Ignore them. They are just for wild people who are not careful.
- c. Skip over that part, because it takes too long to look up what they mean.
- d. Do everything suggested, except wear goggles, because goggles make it hard to see clearly.

Question 8 

Marks: 1

Which of these is the BEST definition for hypothesis?

Choose one answer.

- a. the first guess that comes to mind
- b. a variable in an experiment that is not changed
- c. a guess that is "outside the box"
- d. a reasonable and educated possible explanation based on what you know and what you observe.

Question 9 

Marks: 1

When designing an experiment, the first step is to ____

Choose one answer.

- a. form a hypothesis
- b. test a hypothesis
- c. draw a conclusion
- d. recognize a problem

Question 10 

Marks: 1

Match each word with its meaning.

any representation of an object or an event used as a tool for understanding the natural world

Choose... 

combining what you already know with the new facts that you are given to decide if you should agree with something

Choose... 

observations, perhaps recorded in the form of descriptions, tables, graphs or drawings

Choose... 

Question 11 

Marks: 1

If a report says it has been scientifically proved, then you can believe it.

Answer:

- True False

Question 12 

Marks: 1

Scientists must be fair, and not base their conclusions on ____.

Choose one answer.


- a. evidence
- b. models
- c. opinions
- d. experiments

Question 13 


Marks: 1

Match these meanings with the vocabulary words.


The process of learning more about the natural world.

Choose... 

An educated prediction about what will happen in an experiment.

Choose... 

To draw a conclusion based on something you observe.

Choose... 

Question 14 

Marks: 1

Why do scientists share information?

Choose one answer.

- a. so everyone will know how smart they are.
- b. so no one else will study that problem
- c. so other scientists can continue their work or try to duplicate it.
- d. so other people won't copy them

Question 15 

Marks: 1

What does it mean to make an inference?

Choose one answer.

- a. reach a conclusion based on observations
- b. make a wild guess without much thought
- c. make observations
- d. test repeatedly

Question 16 

Marks: 1

A forest ranger is working in what field of science?

Choose one answer.

- a. Life Science
- b. Earth Science
- c. Physical Science

Question 17 

Marks: 1

Which of these skills would NOT be a skill that a good scientist would use?

Choose one answer.

- a. observing
- b. lying
- c. thinking
- d. investigating

Question 18 

Marks: 1

What are the three interacting parts of a system?

Choose one answer.

- a. independent variable, dependent variable, and constant
- b. hypothesis, experiment, and conclusion
- c. structures, cycles, and processes
- d. questions, answers, and predictions

Question 19 

Marks: 1

If an experiment has a burning fire as a symbol in the directions, it means ____.

Choose one answer.

- a. Wear an apron so that you don't get burned.
- b. You must do this experiment by a campfire.
- c. Do NOT use fire in this experiment.
- d. This experiment will require the use of an open flame.

Question 20 

Marks: 1

Which of these increases the reliability of a scientific explanation?

Choose one answer.

- several likely explanations
- vague statements
- notes taken after an investigation
- repeatable data

Question 21 

Marks: 1

Questions help scientists find out the truth.

Answer:

- True
- False

Question 22 

Marks: 1

Classify each model by its type. Answers may be used more than once, or not at all.

crash test dummy

Choose... 

an artist's sketch

Choose... 

path hurricane is expected to take

Choose... 

mathematical equation of a concept

Choose... 

Question 23 

Marks: 1

What are the variables that do NOT changes in an experiment?

Choose one answer.

- dependent variables
- constants
- independent variables
- inferences

Question 24 

Marks: 1

Physical science has two general fields. What are they?

Choose one answer.

- a. geology and physics

- b. biology and medicine
- c. chemistry and physics
- d. astronomy and geology

Question 25 

Marks: 1

In science, observations and inferences are always agreed upon by everyone.

Answer:

- True False

Question 26 

Marks: 1

A good scientist must know all the answers about his/her topic.

Answer:

- True False

Question 27 

Marks: 1

Which of these questions CANNOT be answered by science?

Choose one answer.

- a. Questions about personal problems or right and wrong.
- b. Questions about how the human body works.
- c. Questions about stars, planets and moons
- d. Questions about how to make tools that will make our life easier.

Question 28 

Marks: 1

The safety symbol that looks like a bleeding finger means ___.

Choose one answer.

- a. You will cut yourself when you do this experiment. Be tough.
- b. Cover all cuts with bandages to prevent bleeding on the experiment.
- c. You must prick you finger to get a sample of blood for this experiment.
- d. Sharp objects will be used. Be careful to prevent cutting yourself.

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APPENDIX I

INTERVIEW QUESTIONS

Interview questions

1. One the first day of school, I showed you all two glasses with clear liquids and ice cubes. You observed them and noticed that the ice cubes floated on one glass, but went to the bottom in the other.

Tell me you thoughts as you made that observation and thought about WHY those ice cubes were on the bottom of the glass.

I have never told you the answer, yet I told you the materials were all common household items. Did any of you experiment at home to make ice cubes that went to the bottom of the glass? Why or why not?

2. What do you think would be a good balance between experiments and textbook activities? Explain your reasoning.

3. What are the pluses and minuses of working in a group? Do you like working in a group, or would you rather work alone?

4. What have you learned about data tables and graphs this year? Do you think they are useful to scientists? Are they useful in science class?

5. What comments do you have about your experiences this year in science class? What could I do as a teacher to help students learn and remember?