A PERSONAL STUDY OF SCIENCE  PROCESS

SKILLS IN A GENERAL PHYSICS CLASSROOM

A Capstone submitted in partial fulfillment of the requirements for the degree of Masters
of Arts in Education, Natural Sciences/Environmental Education
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CHAPTER ONE: INTRODUCTION

Science process skills are the skills scientists use to do science. Common science process skills are observing, inferring, predicting, classifying, measuring, and communicating (Rezba, 1995). Experimentation is the most interesting aspect of science class and students cannot do experiments without science process skills. If students are not experimenting with their own questions they will be memorizing the results of other scientists and memorization decreases their interest and motivation.

> I created a curriculum that would teach science process skills through direct instruction, activities, and experiments. This curriculum was designed for eleventh and twelfth graders in General Physics classroom. For six years I have taught General Physics, General Chemistry, and Inquiry Science at Central High School, a large urban high school, in St. Paul, Minnesota. This curriculum can be adapted as an introductory unit for any one of the above classes.

According to Anderson, Herr, and Nihlen (1994) I engaged in practitioner research because I was at the center of the study I evaluated. I had insider knowledge of what happened in the classroom and I took action and then reflected on that action. My actions were deliberate and carefully planned. I carefully crafted three weeks worth of lessons that I believe taught science process skills.

I wanted to study a problem that occurs in my classroom. I believe students have trouble conducting experiments because they lack science process skills and labs provide important exploratory experiences for students. My plan was to teach my students these skills and study the effectiveness of my teaching.

Experimentation is more than just learning the right answer by following a procedure. Although taking direction is important, students learn how ideas actually interact. For example, they learn how friction, mass, and force all interact under Newton's 2$^{nd}$ Law when they preform an experiment. Students will remember the experiment much longer than the lecture. Plus experiments can allow students to test their own ideas.

I have three types of labs. The first type of lab is very straight forward. Students follow a procedure and answer questions. In the second type of lab, students are given a building objective and a list of materials to achieve that objective. The third type is inquiry based and allows students to pick a topic and develop a procedure. Students are very motivated during inquiry and building labs.

The first type of lab is a standard "cookbook" lab and students can be very bored when they blindly follow a procedure. They don't have any input into the direction of the lab and the lab topics may not address their questions. Sometimes they already know the answers to the lab's questions because it is written in the book. They feel that they are just replicating someone else's work.

The most popular type of lab involves building. For example I will tell them to make the tallest paper tower possible with five sheets of paper, glue, and scissors. One tower was almost taller than my room. About half of my students initially struggled with this assignment because the did not have any experience building three dimensional objects with their hands. These struggling students make several attempts using multiple pathways before they built their tower. Each attempt provides a learning opportunity for the students. The final result was tower but students learned many other skills.

I assess the building labs by the physical product.  I have tried to get student to write a lab report analyzing what factors helped them build their object, but their answers were vague.  A student may build an object that meets the objectives, but they may not have analyzed why it works. They may need additional experiments or more building labs or more information from me.

Inquiry labs are great when students have some familiarity with the topic because they will need to develop a question/hypothesis from their experience.  To compensate for a lack of knowledge, sometimes I will provide a dependent variable and students will identify their independent variable and create their hypothesis.  Defining the dependent variable also focuses the students on one topic, reduces materials, and can help me direct learning but allow students flexibility and the ability to answer their own questions.

If I want my students to participate in inquiry based labs, then they need to know how to create an experiment that properly tests variables.  Identifying and controlling for certain variables is difficult for students.  They lack the background knowledge to make judgments concerning the affects of certain variables and they lack the ability to know how to control for certain variables.

Inquiry labs are important because they allow students to test their own ideas and learn by experience rather than memorizing the book.  Inquiry labs also teach science process skills.  Students can use these skills to test ideas from the newspaper, TV, and internet. Science process skills can be used by anyone outside of my class to test an advertisement claim for a product or a scientific claim made by a news article.  All science facts can be tested if students know how to follow the scientific method.

I propose that if I teach my students how to apply the scientific method, using science process skills, they will use it and remember it when completing labs or thinking about scientific inquiry. Science process skills can be used beyond physics and into adult life.

Although the scientific method is taught every year in science class, students forget certain steps and skills. Then they cannot perform an inquiry lab if they don't know how to formulate a hypothesis or differentiate between variables. Science process skills are what students use to conduct an experiment.

I will evaluate my students' science process skills with the Test of Integrated Process Skills, TIPS, (Shive, 2002), which was created by Okey, Wise, & Burns. During my literature review I found this test has been used in several studies about teaching science process skills to students. Then I will teach students science process skills using a variety of activities. Students will execute an experiment of their own design and write a lab report about the experiment. Finally, students will take TIPS again and I will compare their scores before and after learning about science process skills.

CHAPTER TWO: LITERATURE REVIEW

Learning discrete facts without the ability to lean how to discover more facts is very boring and limiting to students. Science process skills allow student to do science. The current paradigm of science teaching includes teaching how to do science with teaching science concepts. For students, learning the process of science is as important if not more important than learning science concepts. Teaching them science process skills allows them to do science outside the classroom without the assistance of a teacher.

Importance of Science Process Skills

Applied science tries to solve existing problems. Problem solving ability is more important than science knowledge. Scientists need to determine how to find the right answer in addition to knowing the right answer. Therefore, they will be performing several experiments using science process skills.

Students are also learning like scientists. Although most student questions have been answered, allowing students to learn them using experiments is better than telling them the answer. Students are more motivated when they can test their ideas in the lab (Arena, 1996).

Inquiry style experiments increase student motivation because students can test ideas that have relevance to them. Every student has their own past experiences, misconceptions, talents, and skills. One specific question could explain all of the content

to them.  Or they may need a series of several experiments, testing different ideas, for them to understand the material. Standard labs do not explain what every students needs to know to understand science.

Students need science process skills because they need to know how to question and how to determine the relationship between two variables or discover and explain a phenomenon. For teaching the how must be emphasized more than the what (Yager, 1994).  Students need science process skills to test ideas and facts, otherwise science becomes a memory test and memorizing facts reduces student motivation.

Science process skills allow students to tie new information to old information. Students gradually build small facts together to produce a larger understanding of the concept (Wynne, 1999). Students need the ability to test old and new ideas using science process skills, to build meaningful relationships between facts.

Science process skills can help teach science content because students are more motivated to learn and students are learning the answers to their questions. Students take ownership of their experiment and they will more likely remember the information.

Science Process Skill Standards

Science process skills are emphasized at the state level, at the national level, and at the international level  (Wynne, 1999).  Minnesota has created a set of standards for each of the disciplines in the sciences and one more set that describes the history and nature of science.  All classes are expected to teach "how to design and conduct an experiment" (Minnesota Academic Standards Committee, 2003).  At the national level, Project 2061 created the Atlas of Science Literacy (2001) and it also describes the "nature of science" and how certain skills work together.

Science Process Skills

Science process skills are a set of skills that help a student do science. As a student matures and gains more experience, they will use more advanced science process skills.  Researchers vary on how many science process skills they identify and classify into the basic and advanced groups.

Most researchers agree the basic science process skills are observing, inferring, predicting, classifying, measuring, and communicating (Rezba, 1995; Wynne 1999; Arena 1996; Rillero, 1998).  All of these skills are interdependent but observation is often the first skill. Scientists start with what they can observe, either through their senses or through instrumentation and then they try to explain it.

Rezba (1995) describes a large set of integrated science process skills that expand on basic science process skills: identifying variables, defining variables operationally, constructing hypothesis, acquiring and processing data, constructing a table of data, constructing a graph, describing relationships between variables, analyzing investigations, designing investigations, experimenting.  This list does not show how each skill builds on other skills and combined with other skills creates a new skill. For example classifying leads to identifying variables and defining variables operationally. Predicting leads to the construction of a hypothesis only with the help of identifying variables.

Teaching Science Process Skills

It is difficult to teach such a large number of basic and advanced skills. Each skill must be taught overtly but their interdependence can hinder as well as help their instruction.  High school students vary in their experience and proficiency of using

science process skills correctly. Plus the addition of content knowledge to the instruction of science process skills can diminish a students ability to learn each skill.

Six basic science process skills are identified in this paper. Ten more skills are listed as advanced science process skills, for a total of sixteen skills. The sheer number of skills means some skills may not be addressed in every classroom but Turping and Cage (2004) have shown teaching science process skills is worth the instructional time.

Students need to be explicitly taught each skill more than once and they need to use these skills often (Kok-Quntoh & Woolnough, 1994). Teacher modeling also helps students learn (Germann, et al., 1996). Even if a student designs and conducts an inquiry experiment, a teacher cannot assume that student understood every skill. Due to the interdependence of the skills, a student can create a procedure that does not consider certain control variables and his or her conclusions will not be accurate.

A large high school with a diverse population will bring together students of different cultures and socioeconomic backgrounds, as well as different preparedness for science. Students' experiences with science and skills will encompass an enormous range. Some students will have performed informal and formal science experiments outside the classroom, while other students may have struggled to perform science experiments in elementary school and middle school. Germann (1994) discovered academic ability, content knowledge, language preference, parents' education, attitude toward science in school and a student's cognitive ability can affect a student's proficiency in using science process skills.

Duggan, Johnson, and Gott (1996) found that students have trouble defining independent, dependent, and control variables. Specifically, it was difficult for students

to classify their variables as categoric or continuous. An experienced researcher would know to classify their variables because each type of variable leads to different types of data collection in a procedure, which influences data representation in a graph, which would influence the type of conclusions drawn.

Science content is just as important as science process skills. A student's understanding of content information influences the assessment of science process skills (Harlen, 1999 & Wynne 1999). Kok-Quntoh et al. (1994) researched the generalisability of science process skills. They found that students could not transfer interpreting skills between experiments. As a skill, interpreting requires knowledge of the experiment's subject. It is not easily taught as a stand alone skill.

Teachers must overtly teach and model all of the science process skills. Students should use these skills and the teacher must teach them again. Experience can improve students' aptitude with skills. Teachers must be careful that students can use science process skills proficiently before they test content material using science process skills.

Science Process Skills Outside the Classroom

Science process skills enable students to do experiments inside and outside the science classroom. They can also help students do well in other academic areas like reading and writing. Science process skills teach students to think critically about an idea or subject and solve problems.

Once a student learns how to conduct an experiment by testing a hypothesis, control certain variables, and communicate their results, they can do experiments that interest them. For example a student may want to learn how a fan works and he or she

has studied circuitry in physics. If they have the equipment, they conduct their own experiments.

It's important that students understand science process skills and are not randomly testing ideas. If they do not properly control for certain variables, their "tests" will reinforce misconceptions. If the same student from the preceding example were to test how current is affected by resistance but did not control for voltage, they may not understand how the three variables influence each other.

Science process skills build critical thinking and problem solving skills, which can be used in other academic areas. According to Rillero (1998, p. 3), science process skills can also help students "read, write, and do social studies and mathematics." For example students have to write conclusions in their lab reports by making inferences from data. Conclusions also need to be made when the student reads a novel, a play, or a newspaper. While reading the newspaper, a student can think critically about the evidence presented in the article and create a conclusion.

Science process skills build deduction skills that can be used to learn science beyond the science classroom. Teaching science process skills can help students learn non-science knowledge.

Science process skills are how scientists perform experiments. Once students learn these skills through practice, they can create their own experiments. Science process skills build solving problem abilities and critical thinking skills, which can be used for more than just science.

METHODOLOGY

Demographic*s*

      General Physics is a rigorous course that prepares students for college. Most of my students plan on attending college but they don't usually major in chemistry or physics.  Many students take physics because they believe it will make them look more attractive for admission to college.

      I teach at Central High School in St. Paul, Minnesota. Central is the largest high school in St. Paul Public School District.  According to the 2005-06 statistics [Table 1], the student population is 2201 and 22 languages are spoken in students' homes.

Table 1

Racial and economic demographics of Central for 2005-2006

| Race of Reconomic Level | Percent of Study Body |
| --- | --- |
| Caucasian-American | 37% |
| African-American | 31% |
| Asian-American | 26% |
| Hispanic American | 5% |
| Native American | 1% |
| Free and Reduced Lunches | 49% |

Table 2

Racial demographics of General Physics classes 2005-2006

| Race | Percent of Study Body |
|---|---|
| Caucasian-American | 34% |
| African-American | 25% |
| Asian-American | 37% |
| Hispanic American | 4% |
| Native American | <1% |

Until I had compiled data for Table 2, I did not realized a lower percentage of African-American students take my class than in the general population. My peers in the Science Department have discussed the low enrollment of African American students in the honors science classes. Several teachers have tried to offer support and encouragement to increase retention of African American students. Although I give encouragement to all of my students, I have not made a specific effort to recruit and retain African American students.

A much higher percentage of Asian-American students take my physics class than are present in the general school population. The largest population of Asian cultures at Central is Hmong and they are generally first or second generation Americans and can speak English fluently.

Language skills can be a big barrier in science and especially in General Physics. Students must know English well to learn most advance science topics and my class is based on concepts rather than math. Students learning English will struggle with reading

the textbook, homework assignments, and test questions.  Students must describe how variables are related through words instead of numbers.  Therefore, I have found that many students drop out of the class because their language skills could not keep pace with the class.

Pretest Demographics

On the pretest answer sheet I asked students to record their gender, GPA, and previous coursework.  I wanted to learn if any of these factors might be correlated to knowledge of science process skills.  I thought previous grades and courses may indicate performance in the classroom. I also wanted to learn if students who took International Baccalaureate (IB) science courses know the scientific method better than students in general science courses because the IB curriculum requires students to develop their own hypothesizes and procedures.

I had no idea so many students would have difficulty completing the demographic section of the pretest when I designed it.  There was confusion over current GPA and whether I wanted weighted or unweighted GPA.  Most students did not complete the previous course section or their answers were very vague.

I abandoned the demographic section of the pretest because most sections were not completed by a majority of students.  Their answers could have shown a relationship between various variables.  Due to poor response on the pretest, I decided not to include this section in my posttest and I did not make any conclusions from these variables.

Pre- and Posttest

The Test of Integrated Process Skills (TIPS) has been used in several different research studies to assess science process skills.  Dillashaw and Okey (1980) recommend

teachers use TIPS when measuring science process skills to determine the effectiveness of a certain teaching protocol or supplementary materials.

TIPS has 36 questions that test students' ability to identify and define variables, hypotheses, and draw conclusions from tables and graphs in a multiple choice format (Onwuegbuzie, 2001 & Dillashaw et al., 1980). The test is not content specific, so a biology teacher and an astronomy teacher can use the test. TIPS is designed for middle school to high school students. According to Dillashaw et al. (1980) eleventh grade students would need approximately 25 minutes to complete the test.

I gave students the TIPS before the lessons as a pretest and then I modified the test slightly and gave it to them again as a posttest. I added 12 new questions about scientific notation and metric conversions to the posttest because TIPS did not cover all of the material learned in the unit. My introductory units always include metric conversions because students think in English units and physics uses metric.

A few students were absent the day of the posttest, so they took the make up test, which has the same pretest questions and 12 multiple choice questions similar to the posttest. Only the results of the TIPS questions were included in the results section.

One last question was added to the posttest. It was a short answer that asked students to record 2 observations and 2 inferences about the ceiling. My tests include many different styles of questions: multiple choice, True/False, and short answer. Since each style tests students differently and some students are better at certain styles than others, I felt it was important to include an short answer question to the test which was all the questions were multiple choice.

Summary of Lessons

Over the years I have made subtle changes to my curriculum. The introductory unit had a few lessons on observations and inferences, laws, facts, and theories, scientific method, and unit conversion. I expanded each of these lessons and added several lessons that teach specific components of the scientific method and how to perform an independent inquiry experiment. My lecture notes, student instructions, worksheets, and student instruction sheets can be found in the Appendix.

*Day 1*

I explained my expectations and administrative rules to the students. Although I have juniors and seniors, they can act inappropriately. Students would like to know how the class is administered. I explain all of these rules in the first day and in my syllabus.

Next I told them about this project. I also included an explanation in my syllabus for parents to read. I felt it would be unfair if they didn't know their test scores would be studied. For the purposes of this research, I did not label scores with names of students. Instead I grouped them by hour.

Finally, I gave them the TIPS pretest. Students had 30 minutes to complete the test. To reduce paper consumption, the test was administered as a packet and students were given an answer sheet to record their answers.

*Day 2*

I explained safety procedures and showed them the location of all safety equipment. Students were given 10 minutes to read the safety contract and then given a safety test. If a student finished their safety test before the end of the period and they had not finished their test from day 1, I gave them the rest of the period to work on it.

*Day 3*

I explained the nature of science and how to study physics. For an outline of the lesson, see Appendix A, Day 3: Nature of Science. This lesson teaches students what they would study and how to study it. Physics can be difficult because it requires students to think spatially, their opinions about motion will be challenged, and they will have to mathematically explain how variables interact.

My students looked emotionally drained from taking the pretest and safety test, so I designed a very simple experiment, "Leaning Tower of Paper." For an outline of the lesson, see Appendix A, Day 3: Nature of Science, Part C. I gave them an objective and a list of materials. I did not give them a list of instructions because I wanted them to think spatially without the restraint of physics vocabulary. The results from this experiment told me which students had experience working with their hands and could think spatially.

*Day 4*

I began teaching students about science process skills. I started with observations because scientists decide what to study based on what they see. I used several fun examples to pique students interests. For an outline of the lesson, see Appendix A, Day 4: Observation and Inference. I modeled how to identify observations and inferences until students could do this on their own. See Appendix B, Observation and Inference for a copy of the student assignment. This lead to a philosophical discussion over what can truly be observation when we infer so much meaning into observations. My main goal is to get students to think about what they observe and discern what they see from their own judgments.

*Day 5*

I extended the observation and inference concepts into day five. Day four's lesson only addressed pictures and sight. I wanted students to use their knowledge for actions, movements, and the other four senses because most of modern physics cannot be seen directly. Physicists use instruments and other devices for receiving data. For an outline of the lesson, see Appendix A, Day 5: Observation and Inference 2. I had students play Charades and Pictionary because I wanted them to make interpretations, inferences, based on their observations of drawings or actions. For a list of words used during Charades and Pictionary, see Appendix B, Words for Charades and Pictionary. Then students had to make observations about mystery boxes without their eyes to reinforce that observation is more than just seeing. Students guessed what was inside, inferences, based on their observations. See Appendix B, Observation and Inference 2 for a copy of the student assignment.

*Day 6*

We discussed the different levels of evidence. I did not want to engage a discussion about controversial topics like the Big Bang or Evolution but I wanted to present how theories, facts, and law differ. I teach a lot of laws and students need to understand how data and facts from experiments create laws, which is supported by the Minnesota Academic Standards for Science (MASS, 2003) and the American Association for the Advancement of Science (AAAS, 2001). For an outline of the lesson, see Appendix A, Day 6: Levels of Truth and How to Arrive at It. Students read articles from the Flat Earth Society and we discussed how someone would reject or accept evidence from this source. See Appendix B, Is it Science for a copy of the student assignment. I

wanted students to learn that theories are based on laws and facts but they cannot be "proven" true.

In the past few days students had learned the first science process skill, observation, which leads to the first step in the scientific method. For an outline of the lesson, see Appendix A, Day 6: Levels of Truth and How to Arrive at It, Part B: Scientific Method. Therefore, I thought it would be appropriate to start reviewing the scientific method. I realize that students should have been taught these steps every year they have been in science but most forget that it starts with their observations and questions and not a hypothesis. Students are used to starting a lab with a hypothesis because their teacher has already determined the goals of the lab. I wanted my students to engage in a student directed inquiry experiment, so I needed them to learn all of the steps.

To aid my students in writing their own conclusions I taught them RERUN (author unknown). This type of conclusion asks them to explain what they did, why they did it, their results, errors, and new questions. See Appendix A, Day 6: Levels of Truth and How to Arrive at It, Part B: Scientific Method for a full explanation of RERUN. I have used this method for several lab reports after I taught this unit. Students have gotten better at explaining their data and the errors they see in their experiment.

*Day 7*

I started the class with a questioning exercise, Generating Questions Activity. For an outline of the lesson, see Appendix A, Day 7: Developing Questions. Students were asked to look around the room and write questions of what they see. See Appendix B, Generating Questions Activity. I created two versions of this worksheet to reduce copying and increase the variety of students' answers. These questions sparked interest

and frustration in students because the questions' topics were very vague but that is the reality of science. Sometimes scientists have trouble deciding what to research because there are so many questions.  Due to the weather this lesson was held in my classroom, so students had to be creative with their questions. The outdoors would have given them more possibilities.

I wanted students to use the first part of this lesson as inspiration for starting their student designed experiment.  Students started listing what they wanted to study on the Developing Questions Worksheet, which is the second half of the Generating Questions Worksheet (see Appendix B, Generating Questions, Part B: Developing a Question). They listed characteristics of what they wanted to study and developed these into an independent variable. This allowed students to grow from observations to questions to the beginning of a hypothesis and reduced the pressure on students to select only one question and then turning it into a hypothesis.

*Day 8*

We discussed the important characteristics of independent, dependent, and control variables. For an outline of the lesson, see Appendix A, Day 8: Developing a Hypothesis. Then students began to identify what they wanted to study and creating a hypothesis on the Developing a Hypothesis Worksheet (see Appendix B). Since every experiment is different and had different needs, I could not lead a whole class discussion on how to write their hypothesis, but the Generating Questions Activity, Developing Questions Worksheet, and the Developing a Hypothesis Worksheet provide detailed guidance for students to start creating their experiment.

*Day 9*

I spent a little time reviewing control variables because they are indirectly addressed in a procedure. For an outline of the lesson, see Appendix A, Day 9: Designing an Experiment.

The Designing an Experiment Worksheet (see Appendix B) reviewed selecting and developing a question, identifying variables, creating a hypothesis, and creating a procedure. Students also included a materials list and safety precautions.

It was important for me to carefully read the Designing an Experiment Worksheet because I needed to assess if their procedures could test their hypothesis safely in the laboratory. Therefore, the next few assignments did not focus on the experiment. I had a lot of students switching between classes, adding or dropping Physics, and absences. It was important to have a few days between generating the procedure and executing the procedure. I could talk to students who were absent and they could have a few days to make adjustments to their procedure. I also needed time to procure materials or ask students to bring in those materials. Finally, I wanted students to be aware of safety procedures they needed to follow during the experiment.

*Day 10*

We switched topics and talked about data tables and graphs. For an outline of the lesson, see Appendix A, Day 10: Graphing. I talked broadly about tables and highlighted the bar graph, the pie graph, and the line graph. We read and make a lot of graphs in physics to highlight numerical relationships between different variables. I had students complete a worksheet assignment called Tables and Graphs (see Appendix B).

*Day 11*

I explained how to convert between metric units. For an outline of the lesson, see Appendix A, Day 11: Metric Conversions and see Appendix B, Metric Conversions for student assignment. Units are very important in physics because most of the data is quantitative. During the first semester students have to use a lot of distances and they need to understand relative size and how to convert between millimeters and meters. Units describe formulas and relationships between variables because physics combines many variables together like distance and time to make speed.  Students do not need to memorize formulas if they understand and can use units appropriately.

*Day 12*

I briefly explained how to convert between English and Metric units and vice versa. For an outline of the lesson, see Appendix A, Day 12: Advanced Metric Conversions and Scientific Notation and see Appendix B, Advanced Metric Conversions and Scientific Notation for student assignment. Since my students think in English units (i.e. miles instead of meters), they do not understand that 55 km/h is slow.  By learning how to convert, students can double check if numbers make sense.

I also taught scientific notation because a lot of science is done on very small numbers (the wavelength of light) and very large numbers (the frequency of light).  For an outline of the lesson, see Appendix A, Day 12: Advanced Metric Conversions and Scientific Notation, Part B, Scientific Notation and see Appendix B, Advanced Metric Conversions and Scientific Notation for student assignment. I wanted students to able to understand the numbers and calculate problems using scientific notation. In this lesson I only used numbers but in future problems students will need to understand relative sizes of certain variables and units.

*Day 13 & 14*

Students completed their experiments and I did not give any formal instruction. My role was to observe and answer student questions. Once students started their experiment they realized they had to make adjustments in their procedures, so they had plenty of questions. This was also a time for students to write their lab reports. I gave the students the rubric for assessing the lab report. See Appendix B, Scientific Investigation Rubric for a copy of the rubric.

*Day 15*

Lab reports from the experiment were due. As a class we reviewed all of the topics learned in class. I completed several math problems similar to their previous homework assignments and I reviewed important vocabulary. Students asked me questions and I described how to solve several problems. Students were given a review assignment to complete. See Appendix B, Review for a copy of the student assignment.

*Day 16*

Students took the posttest. All student work that was not previously collected was due with the test.

RESULTS

Analyzing Pre- and Posttest Data

A comparison of the pre- and posttest scores will show if the new science process skill curriculum was helpful to students. The pretest was designed to collect gender, GPA, and previous coursework demographic data from students. However, many students forgot to answer these questions or did not know their current GPA, so I disregarded this data.

Pre- and posttest data was not paired because my sample size would have been too small. Some students could not complete the pretest after two days and it would be inaccurate for them to take the pretest after learning some of the material. Some students dropped the class before taking the posttest and their pretest scores were not removed. Some students were added into the class after the pretest. Some students changed hours but their pretest score stayed with their original hour and some students have yet to take the posttest.

Pre- and Posttest Data

Each class, assigned by hour, was tabulated and averaged. The average pretest score and posttest score are listed. The test had 36 questions.

Table 3

Pre and Post Scores by Hour

| Hour | Average Pretest Score | Average Posttest Score | Positive Growth |
|------|------------------------|-------------------------|-----------------|
| 2 | 26 | 27.5 | 1.5 |
| 3 | 22 | 25.5 | 3.5 |
| 4 | 23 | 27.2 | 4.2 |
| 5 | 23 | 26.1 | 3.1 |
| 6 | 21 | 24.3 | 3.3 |
| Average | 23 | 26.1 | 3.1 |

I classified test questions into four categories: variables, tables/graphs, procedure, and hypothesis. The variable category was further broken down into control, dependent, independent, and general. Some of the questions in the variable category could not be classified as a control, dependent, or independent and were listed as "variables."

Table 4

Grouping Test Questions by Type and Assessing Student Scores

| Type of Question | Number of Questions | % of Pretest Correct | % of Posttest Correct | Growth |
|------------------|---------------------|----------------------|-----------------------|--------|
| Control | 3 | 45.1 | 66.1 | 21.0 |
| Dependent | 6 | 59.9 | 61.9 | 2.1 |
| Hypothesis | 10 | 64.5 | 73.6 | 9.1 |
| Independent | 3 | 38.2 | 55.7 | 17.5 |
| Procedure | 3 | 76.2 | 82.0 | 5.8 |

| | | | |
|---|---|---|---|
| Tables/Graph | 6 | 83.7 | 87.4 | 3.7 |
| Variables | 5 | 69.0 | 74.0 | 5.0 |

Lab Report Scores

      At the end of the unit students wrote a lab report for their experiment. Each group was given a rubric (See Appendix, B Scientific Investigations Rubric) to explain the grading guidelines. Each lab group had to write one report and it was due the day before the posttest.  Maximum possible points were 40.

Table 5

Lab Report Scores by Hour

| Hour | Average Lab Report Score |
|---|---|
| 2 | 35.4 |
| 3 | 34.3 |
| 4 | 33.5 |
| 5 | 34.3 |
| 6 | 34.4 |
| Average | 34.4 |

Student and Teacher Comments

      I recorded impressions from students and my own thoughts of the lessons.

I gave the pretest on the very first day.  My general feeling was that no on wanted to take the test.  Some students asked me if the test was for credit and I said no.  This could have affected their scores.

One student cheated on the test. He was bluntly looking at his neighbor's test. He told me that the test was easy but he was tired and didn't want to take it.

The very first lab activity was building a tower out of paper. Several students asked me how to build the tallest tower. The lack of instructions frustrated some students. There was no way a student could have prepared for the lab unless they had experience building with paper. Over all, most students liked the lab because they could work with their hands.

My students also enjoyed analyzing cartoons for observations and inferences. Once they learned the vocabulary they debated the categorization of answers.  I am not sure if they knew how this information applied to the class.  The next class day I explained that observations belong in data and inferences belong in conclusions.

However, many students thought observation was limited to sight.  The next assignment asked them to guess, infer, the contents of a mystery box.  Their observations were limited and many boxes had the same observations and inferences.  A few students got frustrated and opened some of the boxes.

Next we discussed the differences between scientific truth.  As I researched for this lesson, I found several definitions of facts, laws, and theories. I tried to provide the simplest definitions and explain the differences between each level of truth.  Many students thought that theories were guesses.

I had a lot of anxiety about the student designed experiment. I trusted my Generating Questions, Developing Questions, and Designing an Experiment Activities and Worksheets to direct my students from a topic to a lab procedure. Each lab group has a different topic and it would have been difficult for me to guide each group.

My students had trouble selecting an experiment topic. We had only done one physics lab and they did not know what to test when I said their project had to be about physics. So, I brought in Middle School Science Fair books. My students loved the pictures and ideas. Several students had trouble deciding between several choices. One student told me he had one idea to do in class and several he wanted to try at home.

I worried that my students wouldn't have a viable hypothesis or their procedure would be incomplete. I was very worried about safety considerations. However, my students generally enjoyed their projects. There were very few problems because I placed a three day space between when students turned in their procedure and when they executed their procedure. This allowed me to talk to students and discuss their instructions, materials, and safety precautions.

I was worried that in the two days students used to complete their experiment, they would be off task and cause havoc. I was wrong again. They worked diligently on their topic and they seemed very excited about their topic.

The rubric I used was very detailed. Only those students who did not read the instructions had trouble writing their lab report. This rubric made it easier to grade their reports.

CONCLUSIONS

I developed and executed a curriculum on science process skills. Lesson topics include observation vs inference, levels of truth, scientific method, and graphing. Then students developed and executed a laboratory experiment from start to finish.

I wanted students to learn science process skills because I noticed from previous years that students had trouble developing their own procedures, creating graphs, and deciding what information to include in their reports. They were missing important details and they were more worried about getting the correct numerical data rather than thinking and learning about the concepts.

Students were given the TIPS test before and after the unit. Every hour saw an small increase in test scores. Hour two had the smallest increase in scores but they had the largest average pretest score. I can conclude that students knowledge and application of science process skills did increase slightly based on their increase in test scores.

Table 3

Pre- and Post Scores by Hour

| Hour | Average Pretest Score | Average Posttest Score | Positive Growth |
|------|------------------------|-------------------------|------------------|
| 2 | 26 | 27.5 | 1.5 |

| | | | |
|---|---|---|---|
| 3 | 22 | 25.5 | 3.5 |
| 4 | 23 | 27.2 | 4.2 |
| 5 | 23 | 26.1 | 3.1 |
| 6 | 21 | 24.3 | 3.3 |
| Average | 23 | 26.1 | 3.1 |

The test was broken into different types of process skills. Students scored below 50% correct on the pretest for the control and independent variable identification. However, these questions saw the biggest increase in correct scores, 20% and 17% respectively. Students still need more help with variable identification because student scores on the posttest for all four variable categories: control, independent variable, dependent variable, and variables, were less than 75% correct.

Table 4

Grouping Test Questions by Type and Assessing Student Scores

| Type of Question | Number of Questions | % of Pretest Correct | % of Posttest Correct | Growth |
|---|---|---|---|---|
| Control | 3 | 45.1 | 66.1 | 21.0 |
| Dependent | 6 | 59.9 | 61.9 | 2.1 |
| Hypothesis | 10 | 64.5 | 73.6 | 9.1 |
| Independent | 3 | 38.2 | 55.7 | 17.5 |
| Procedure | 3 | 76.2 | 82.0 | 5.8 |
| Tables/Graph | 6 | 83.7 | 87.4 | 3.7 |

| Variables | 5 | 69.0 | 74.0 | 5.0 |
|---|---|---|---|---|

Science process skills are the skills needed to do experiments and lab reports are a much better indicator than a written test. Students did not design and perform an experiment before I taught the curriculum, so I cannot analyze their growth in science process skill application by comparing lab reports.

According to Table 5, the average score for lab reports was a B. The maximum score for a lab report was 40 and a few lab reports earned 40 out 40. Most scores were in the 30s, with a few scores in the 20s.

Table 5

Lab Report Scores by Hour

| Hour | Average Lab Report Score |
|---|---|
| 2 | 35.4 |
| 3 | 34.3 |
| 4 | 33.5 |
| 5 | 3.43 |
| 6 | 34.4 |
| Average | 34.4 |

Many of the reports lacked strong conclusions. Some students did a poor job analyzing their results and discussing errors in their experiment. Prior assignments had addressed variable identification and creating a hypothesis but they had trouble

explaining their results and what they mean, which is consistent with Kok-Quntoh et al. (1994) research. It is much easier for students to identify the proper conclusion from a list than to create one of their own.

I do know that students did enjoy the experiment based on their comments and motivation during the lessons. They liked deciding the topic and developing their own experiment. The activities before the experiment, like Developing a Hypothesis, and Designing an Experiment, provided much of the material needed to write the report. Teaching students how to construct tables and graphs, also helped with data representation.

I learned that there are many science process skills and they are interconnected. It is hard to teach each skill separately but it is just as difficult to explain how they are all connected. I realized that I needed to explain the different kinds of variables and develop more lessons that address variable identification.

If I were to do this experiment again I would make a few changes. I would redesign the pre- and posttests, add more lessons, and redesign a few lessons. If I wanted to collect demographic data on my students I would have them check off a list of choices rather than fill in the blank. I would also indicate if I wanted weighted or unweighted GPA. Finally, I would try to make the lessons for tables/graphs, metric conversions, and scientific notation more inquiry based because they would be more interesting.

Overall, I was very excited about the science process skills curriculum and so were my students. I was pleased to see improvement in my students' science process skills and my students were motivated to learn about science. It was a wonderful unit.

APPENDIX  A

LESSON OUTLINES

**Day 3: Nature of Science**
Materials:
5 sheets of paper for each group, glue, scissors

A. What do Physicists Study:
1. The Universe is made of matter, energy, and motion.  (rock, weight, glass of water)
2. Nature obeys a set of natural laws. Physicists try to explain cause and effect using the simplest explanation.  (ball, cart, rock)

B. How to Study Like a Physicist
-Brainstorm answers with students before reading list.
1. Questions are always appreciated.
2. Read the textbook (maybe more than once).
3.  Complete all of the assignments before the test.
4. If you have trouble with a topic
-Break the problem into little parts.
-Draw a picture.
-Try explaining it to a friend, parent, or a pet.  You will learn more about the topic if you try to teach it.
5. Look for physics in the real world.
6. Actively participate in laboratory experiments.
7. Pay attention in class and listen.
8.  You will need a strong working knowledge of algebra and some geometry.

C. Leaning Tower of Paper
With only 5 sheets of paper and glue how high can you build a paper tower? To earn 20 points for the activity the team must build a tower at least 40 cm high. The team that build the tallest tower in the class earn 10 extra credit points.

**Day 4: Observation and Inference**
Materials:

monster or large mysterious object, several cartoons or pictures on transparencies, Observation and Inference Worksheet

Part A: Introduction to Observation and Inferences
Brainstorm: What is observation? what you see is very detailed-color, shape, size, texture, smell, taste, luster, malleability, state/phase

Question: What is that object at the front of the room? monster

Strategy: Think-Pair-Share -What is that object? Record observations.
1. Individually, students write, draw, or visualize answer.
2. Table groups share answers.
3. Groups share answer to the class.

Brainstorm: What is inference? analyzing observations

Question: What is inside the monster?

Part B: Apply Observation and Inference Skills to Pictures
Show cartoons and have students write their observations and inferences. Model how to observe and infer but as you move through the cartoons, have students do more work. Students should finish this assignment in class and put in their homework packet.

**Day 5: Observation and Inference 2**
Materials:
one cartoon on a transparency, vocabulary words on small slips of paper, box or hat, 12-24 sealed boxes with small items inside

Review: Show cartoon.
What is observation? emphasize all of the senses
What is inference? judgments based on information obtained via the senses

A. Charades/Pictionary (Refer to Appendix B, Words for Pictionary/Charades)
Students come up to the board and pull one of the words out of hat. Then they act out or draw the idea or object. The class guesses the answer.  If it gets too noisy, students should write their answers.

B. Mystery Boxes
Without opening the box students record what they think is in the box (inferences) based on their observations.  Students should record material and shape. Students should finish this assignment in class and put in their homework packet.

**Day 6:  Levels of Truth and How to Arrive at It**
Materials:
Articles from the Flat Earth Society, Is It Science Worksheet

A. Laws, Theories, & Facts
Fact- true statement based on observations, tests, and experiments (can be measured).

Ex: Earth revolves around the sun

<u>Law:</u> describes how an event occurs
Ex: Law of Gravity

<u>Theory</u>: describes how and why an event occurs (comprehensive explanation of a lot facts and laws).
Ex: Theory of Relativity, Cell Theory

F, L, T all must be tested; if they are found wrong, they are rejected and discarded. In order to be valid, scientific knowledge must meet certain criteria including that it: be consistent with experimental, observational, and inferential evidence about nature; follow rules of logic and reporting both methods and procedures; and, be falsifiable and open to criticism.

<u>Peer Review</u>-to be published in a reputable journal, results must be repeatable
<u>Critism</u>-authors must present their work in front of their peers and answer the tough questions

Scientific ideas are incomplete, and opportunity exists in these areas for new advances.
Ex: classic (Newton) physics and modern physics

B. Scientific Method
1. State the problem. What do you want to find out?

2. Research the problem.

3. Create a hypothesis.
-Must be **testable** (materials, time, education).
-Must show **cause and effect**.
-Cannot be a **why** question.

4. Test the hypothesis. Design an experiment that will test the experiment.  Remember to test only one variable. Control for other variables
Ex: If you want to test the effect of size on speed of a ball rolling down a ramp, what would you need to consider? mass, type of material, starting position, angle, initial speed, distance.

5. Observe and record. Organize observations and raw data into a labeled table.  Use a graph to show the relationship between two numerical variables.

6. State a conclusion. RERUN
R=Recall...Describe what you physically did.
E=Explain...Explain the purpose.
R=Results...State the results.
U=Uncertainty...Describe the uncertainties and errors that might exist.

N=New...Write two new things you learned.

C. Searching for Evidence
Question: How can you tell if an article is written with misinformation?

1. Students should write their opinion of the shape of the earth.

2. Students should then read Flat Earth Society Information. As they read, students should record:  facts, examples, expert authority given in the text.

3. Students write reflectively to decide whether they evidence they have gathered from the reading has convinced them that the earth is flat. Students should finish this assignment in class and put in their homework packet.

4. Lead students in a discussion of how complete and convincing the evidence was.

**Day 7: Developing Questions**
Materials:
Generating Questions Worksheets (2 versions to generate a variety of questions)

A. Question Activity (15 minutes)
If possible go outside and complete Question activity. If it is not possible to go outside, then set out a variety of materials and pictures for students to view.

Review Students' Answers (5-10 minutes)

B. Developing a Question
Students perform Steps 1 through 6 about one of the topics on the Question Activity worksheet.
Students should finish this assignment in class and put in their homework packet.

**Day 8: Developing a Hypothesis**
Materials:

Developing a Hypothesis Worksheet

A. Types of Variables
<u>Dependent or Responding Variable</u>-the thing you choose to test in an experiment. Its value will vary or change depending on something else.

<u>Independent Variable</u>-the factor/variable that you vary or change in the experiment or that varies naturally. You will choose one independent variable to test in your experiment.

The Independent Variable causes the Dependent Variable to change. It's a cause and effect relationship or an If/Then statement.

<u>Control Variable</u>-variable that does not change

What Makes for Good Variables?
-Independent variable is measurable and can be changed in the experiment.
-All Dependent variable are defined and measurable and caused by independent variable.

B. Testable Hypothesis:
-Includes an if/then statement that relates independent to dependent variables
-Students should have a reasonable idea of the answer to the hypothesis but not know the exact answer
-Both independent and dependent variables can be measured

A "null" hypothesis suggest that the independent variable has no effect on the dependent variable. Write a null hypothesis for your question.

C. Developing a Hypothesis
Student should complete this worksheet and put it in their homework packet.

**Day 9: Designing an Experiment**
Materials:
Designing an Experiment Worksheet, candle, matches

A. Control variables

To show that only the Dependent Variable changes when the Independent Variable changes, certain variables (**control variables**) must be held constant. One experiment may have several control variables.

Example: Light candle and brainstorm different types of variables.
Dependent Variable: How fast does a candle burn?
Independent Variable: Time measured in minutes
Control Variable: Height of candle measured in centimeters
Control Variable: Use same type of candle for every test

B. Designing an Experiment Worksheet
Student should complete this worksheet and turn into me for my final approval.

**Day 10: Graphing**
Materials:
Tables and Graphs Worksheet

A. Tables:
-Organize data into frequency tables . (Qualitative data)

-Each column should be labeled. Do not forget units!
-Each data set should be on the same row
-Record all data even if it does not look right. Write observations or errors that you see or did. Record these observations in the sources of errors.

B. Pie Graphs (Quantitative data)
-Shows percent of a whole
-Divide desired number by total and multiply by 100
-By hand roughly approximate size
-Do large slices first

C. Bar Graphs (Qualitative data)
-Shows frequency of items
-Items along x
-Frequency along y
-Label x, y, and title

D. Line Graphs (Quantitative data)
-Horizontal Axis should be independent variable.
-Vertical Axis should be dependent variable.
-Label each axis with name and units if appropriate.
-Make tic marks from 0 to the largest data point. Tic marks should be evenly spaced and labeled.  Use graph paper.
-Label the top of the graph with an appropriate title, usually independent vs dependent variable.

Relationships
<u>Direct</u>-As x increases y increase
<u>Indirect</u>-as x increases y decrease

Best Fit Line
After looking at all the data, draw a straight line using a ruler that best follows the trend of the data.  This line can go above some points and below other points. The line represents an "average."

E. Tables and Graphs Worksheet
Students should finish this assignment in class and put in their homework packet.

**Day 11: Metric Conversions**
Materials:
Metric Conversions Worksheet

A. Foundation of Metric System
Based on Ten. Each place has a separate name. Review names.

B. Labeling Metric units

Second name is the type of unit m-length, L-volume, g-mass

C. Ratio Method
Ex: 4m =?cm   1m=100 cm                ratio

$(4m)\dfrac{(100 \text{ cm})}{(1 \text{ m})} =$                multiply by ratio and cancel units

D. Moving the decimal
Move the decimal the number of places between the two types of units

Ex: 52000 mL =?L                If the unit is bigger, the number gets smaller.

Ex:  7.8 m = ?mm                If the unit is smaller, the number gets bigger.

E.  Metric Conversions Worksheet
Students should finish this assignment in class and put in their homework packet.

**Day 12: Advanced Metric Conversions & Scientific Notation**
Materials:
Advanced Metric Conversions and Scientific Notation Worksheet

A. Review Metric Conversions
Review concepts from previous lesson.  Take questions from students about homework
and review answers.

B. Advanced Metric Conversions: Converting between English and Metric Units

To convert speed, time and distance need to be addressed separately. I use the ratio method and each number should be labeled with a unit. Cancel all units until you reach the units used in the answer.

Ex: 25 miles/hour = ? m/s

(25 mile)(1.609 km)(1000 m)(1 hour)   (1 min) =11.17 m/s
(1 hour)    (1 mi)    (1 km)    (60 min) (60 sec)

B. Scientific Notation

Large and small numbers can be easily written and read using scientific notation.  It takes the form of $M \times 10^{n}$ where $1 < M < 10$ and n represents the number of decimal places to be moved. Positive n indicates the standard form is larger than zero and a negative n indicates a number smaller than zero.

Ex: Convert 1,500,000 to scientific notation.

Ex: Convert 0.000085 to scientific notation.

Ex: Convert 1.25 x 10-6 to standard notation.

Ex: Convert 9.87 x 1014 to standard notation.

C. Advanced Metric Conversions and Scientific Notation Worksheet

Students should finish this assignment in class and put in their homework packet.

**Day 11-12 Lab**

Based on students' Design an Experiment W, I will have the appropriate materials ready for them to conduct their tests. An official lab report with conclusion is due at the end of day 12.

**Day 13: Review**
Materials:
All assigned worksheets

A. Collect Lab Reports

B. Review Major Topics
Talk about each of the major topics: Nature of Science, Observation vs Inference, Laws, Facts, & Theories, Scientific Method, Developing a Question Activity, Types of Variables, Developing a Hypothesis, Designing an Experiment, Conclusions, Graphing, Metric Conversions, Metric & English Conversions, and Scientific Notation

Answer questions for students. Model how to solve problems.

C. Review Worksheet
Students should finish this assignment in class and put in their homework packet.

Homework Packet is due with the test.

APPENDIX B

STUDENT ASSIGNMENTS

**Observation and Inference**

1. What is observation?

2. What is inference?

3. What is inside the Monster?

4. Write two observations and two inferences about each cartoon. Label which statements are observations and which ones are inferences

a.


b.


c.


d.


e.


f.


g.


h.

**Pictionary/Charades**
Write each vocabulary word on a small piece of paper and drop into a hat.  Students draw
one name out of the hat and perform that word.

| | |
|---|---|
| Physicist | Scientist |
| Laboratory | Universe |
| Matter | Energy |
| Motion | Meterstick |
| Fire Extinguisher | Fire Drill |
| Beaker | Thermometer |
| Hypothesis | Fire Drill |
| Chemistry | Biology |

## Observation and Inference 2

A. Pictonary/Charades: Write your guess for each item.

1.

2.

3.

4.

5.

6.

7.

8.

B. Mystery Boxes:

| Box Number | Two Observations | Two Inferences |
|---|---|---|
| 1 | | |
| 2 | | |
| 3 | | |
| 4 | | |
| 5 | | |
| 6 | | |
| 7 | | |
| 8 | | |
| 9 | | |
| 10 | | |

**Is It Science?**
What is the earth's shape? Give evidence to support your answer




While reading your assigned article, record facts, examples, and expert authority given in the text.




After reading your assigned article and listening to the discussion, in your opinion what is the earth's shape? Give evidence to support your answer




**Law, Fact or Theory**-Choose the level of proof for each statement (Fact, Law, or Theory).
1) The atomic mass of oxygen gas is 32 amu.
2) Matter cannot be created or destroyed.
3) Carbon-14 is radioactive.
4) All matter & energy in the universe came from a compact, infinitely dense, extremely hot fireball.
5) A body acted on by no net force moves with constant velocity and zero acceleration.
6) If a net external force acts on a body, the body accelerates.
7) If a body A exerts a force on body B, then body B exerts an equal force on body A.
8) Sugar retards the hardening of concrete.
9) All the laws of physics are the same in all inertial frames of reference.

**Scientific Method-**Match the following definitions with correct term.
___ 1) organized process used to test a hypothesis
___ 2) an educated guess about the solution to a problem
___ 3) observation and measurements recorded during an experiment
___ 4) a judgment based on the results of an experiment
___ 5) a logical explanation for why events occur in nature
___ 6) used to show that the result of an experiment is really due to the condition being tested
___ 7) factor that changes in an experiment

| a. hypothesis | b. control | c. variable | d. experiment |
| e. conclusion | f. law | g. data | h. theory |

**Generating Questions Activity A**
*A. Find evidence of each of the items (1-6) listed below. Name or sketch that item. Answer each question.*
1. Something soft
-Speculate why it is soft
-How would you test that idea?

2. Something shiny
-What purpose does it serve for this object to be shiny?

3. The presence of mammals (not humans)

4. An illustration of the principle of "lift"

5. A boundary

6. A relationship

B. Developing a Question
1: List at least five characteristics of one topic you might be interested in studying.

2: Choose one of the above characteristics to study in an experiment. (dependent variable)

3: List 5 factors that might affect the characteristic you have chosen. (independent variable)

4: Choose one independent variable to study in your experiment.

5: List two to five ways that you could vary the independent variable that you have selected.

6: Record the question that you will try to answer in your experiment.

**Generating Questions Activity B**
A. *Find evidence of each of the items (1-6) listed below.  Name or sketch that item.*
*Answer each question.*
1. Something smelly
-What purpose might this object's scent serve?

2. Something that is changing
-What might be causing the change?
-How would you test that idea?

3. Something fuzzy

4. A seed

5. A conflict

6. An improvement

B. Developing a Question
1: List at least five characteristics of one topic you might be interested in studying.

2: Choose one of the above characteristics to study in an experiment. (dependent variable)

3: List 5 factors that might affect the characteristic you have chosen.  (independent variable)

4: Choose one independent variable to study in your experiment.

5: List two to five ways that you could vary the independent variable that you have selected.

6: Record the question that you will try to answer in your experiment.

**Developing a Hypothesis**
Write the question your group developed in the last lesson.

List two to five possible answers for your question.

Analyze each possible answer, and work together to determine which one is most probable. This is your hypothesize: an educated guess about the answer to your question. Your hypothesis should be testable. Write it below, and state why you chose it.  If you don't have any reason to choose one hypothesis, you can list more than one.

Hypothesis:

Why we chose this hypothesis:

A "null" hypothesis suggest that the independent variable has no effect on the dependent variable. Write a null hypothesis for your question.

**Designing An Experiment**

Review:
What is your question?

What is the dependent variable?

What is the independent variable?

What is your hypothesis?

What are your control variables?

Discuss:
We will vary the independent variable by:

We will measure the response of the dependent variable by:

Have you worded the hypothesis so that it can be tested in the experiment?

Design:
List the things you need to hold constant in this experiment.

What sample sizes will you use? How did you choose these sample sizes?

List all of the steps you will carry out to test your hypothesis. BE VERY CLEAR!

Materials:

**Turn in at the end of the hour!!!!!**

**Instructor's Approval** _____

**Tables and Graphs**

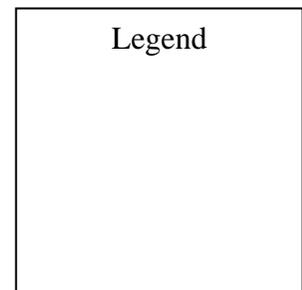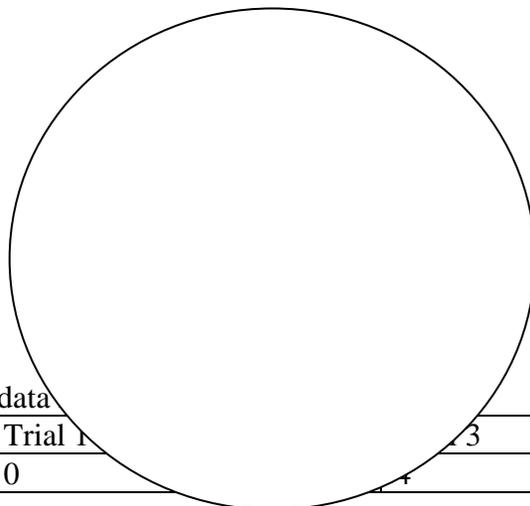Data is always easier to understand when it's in a table.

1. Construct a table that organizes the following data: dog, cat, dog, hamster, dog, dog, bird, cat, cat, iguana, snake, cat, mouse, hamster, bird, dog. What information can your table provide?

Another way to organize the information is to create a bar graph. A bar graph has the items' names on the bottom edge (horizontal or x axis) and frequency on the side edge (vertical or y axis). **Don't forget labels.**

2. Graph the frequency of each type of animal from the data in question #1.
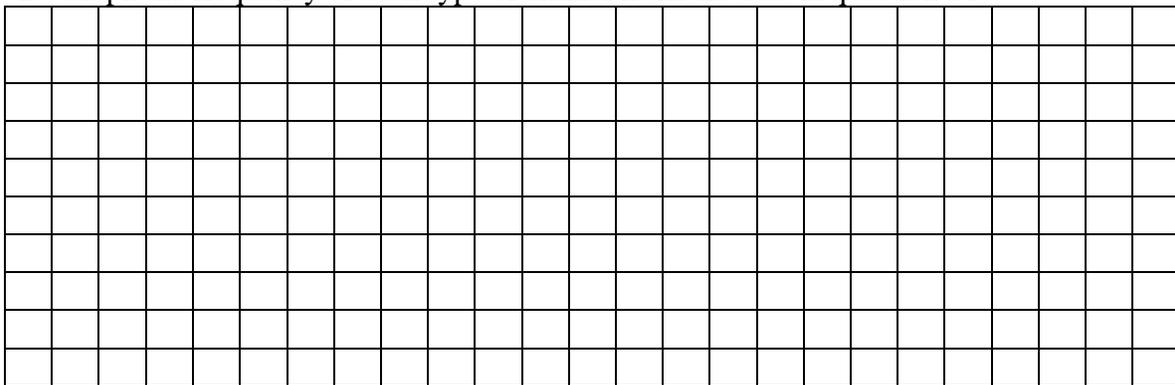
3. Using your table from question #1, construct a pie chart. You will need to convert the number of each type (frequency) into percentages. Divide the number of each type by the total number of animals. Add this information to your table. Then construct a pie chart. Don't forget legend and labels.

Legend

4. Convert the data

| | Trial 1 | | 3 | Trial 4 | Trial 5 |
|---|---|---|---|---|---|
| Height (m) | 0 | | | 6 | 8 |

| Speed (m/s) | 10 | 8 | 6 | 4 | 2 |
|---|---|---|---|---|---|

What type of relationship does height have with speed?

5. Convert the data from the table to the graph.

| | Trial 1 | Trial 2 | Trial 3 | Trial 4 | Trial 5 | Trial 6 | Trial 7 | Trial 8 | Trial 9 |
|---|---|---|---|---|---|---|---|---|---|
| Temp (C) | 0 | 5 | 10 | 15 | 20 | 25 | 30 | 35 | 40 |
| Volume (L) | 10 | 12 | 16 | 18 | 19 | 25 | 29 | 35 | 38 |

What type of relationship does temperature have with volume?

**Metric Conversion**

1) How many meters are in one kilometer?

2) What part of a liter is one milliliter?

3) How many grams are in two kilograms?

4) What part of a meter is a centimeter?

5) If one gram of water has a volume of one milliliter, what would the mass of one liter of water be in kilograms?

6) 35 mL =  ? L

7) 950 g = ? kg

8) 275 mm = ? cm

9) 1,000 L = ? kL

10) 1,000 mL = ? kL

11) 4,500 mg = ? g

12) 25 cm = ? mm

13) 0.005 kg = ? mg

14) 0.0075 m = ? cm

15) 15 g = ? mg

**Advanced Metric Conversions and Scientific Notation**

A. Convert into new units. Do NOT forget to label your answer with a unit.

1. Convert 3 x 108 m/s into mi/hr.

2. Convert 55 mi/hr into m/s.

B. Convert the following to scientific notation.

1) 0.005                                          2) 0.25

3) 5.050                                          4) 0.025

5) 0.0008                                        6) 0.0025

7) 1,000                                          8) 500

9) 1,000,000

C. Convert the following to standard notation.

1) $1.5 \times 10^3$                              2) $3.35 \times 10^{-1}$

3) $1.5 \times 10^{-3}$                           4) $1.2 \times 10^{-4}$

5) $3.75 \times 10^{-2}$                          6) $1 \times 10^4$

7) $3.75 \times 10^2$                             8) $1 \times 10^{-1}$

9) $2.2 \times 10^5$

Science Investigation Rubric

Name: _____   _____   _____

By the time you begin your lab you must have clearly identified your hypothesis, written your procedure, and obtained your materials. Your product is your laboratory report. For full credit your report should contain your hypothesis, procedure (with materials list), observations/data made during experiment, and conclusion (RERUN). You will be evaluated based on the following criteria:

| Criteria/Score | 0 | 3 | 5 | 8 | 10 |
|---|---|---|---|---|---|
| Hypothesis | No attempt has been made | Major flaws and limited or no relevancy | Partially developed with some relevancy | Sufficiently developed with reasonable relevancy | Correctly stated with both variables identified |
| Investigation Design | No attempt has been made | -Test is not relevant to the hypothesis -Information is not sufficient to replicate investigation | -Investigation is a partially constructed test of hypothesis -Some of the components are missing, making it difficult to replicate | -Investigation is a reasonably constructed test of hypothesis -All of the components are reasonably arranged so that the investigation can be replicated | -Investigation is a well constructed test of stated of hypothesis -All of the appropriate components are arranged so that the investigation can be replicated exactly as described |
| Methods of Data Collection | No attempt has been made | -Insufficient data has been collected -Data has not been recorded or displayed in the correct units or in an organized way | -A minimum amount of data has been collected -Data is recorded and displayed but may lack the correct units and organization | -A reasonable amount of data has been collected in a sufficient manner. -Data is recorded and displayed using the correct units and organized methods | -Significant data has been collected in the most efficient and appropriate ways -Data is accurately recorded and displayed using the correct units and most organized methods |
| Conclusion/ RERUN | No attempt has been made | Answers one component of RERUN. | Answers two to three components of RERUN. | Answers four components of RERUN. | Clearly answers all five components of RERUN. |

Total                                                                                    /40

*Your report does not need to be typed but should be legible.
*Please attach this sheet to your report or it will not be graded.
*One report per group.
Adapted from Schneider, M. (2004). Positive pitfalls. *The Science Teacher, 71(5),* 42.
**Review**
1. What do physicist study?

2. What is the difference between observation and inference?

3. What is the difference between a law, fact, a theory?

4. What are the steps to the scientific method?

5. Give 5 observations and 5 inferences about your shoe.

6. Put the following steps of the scientific method in order.
___ Research the problem.
___ Observe and record.
___ Make a hypothesis.
___ Identify the problem.
___ Arrive at a conclusion.
___ Test the hypothesis.
7. How can you tell if an article is written with misinformation?

8. What is the difference between independent and dependent variables?

9. What is important in a good hypothesis?

10. What is a direct relationship between two variables?

11. Draw the graph for an indirect/inverse relationship?

12. What type of graph would you use to show percents of a whole?

13. What is important in a conclusion?

| | |
|---|---|
| 14) 55 L = ___ mL | 15) 9.88 g = ____lb |
| 16) 6.53 m = ___ mi | 17) 25,589 mg = ___kg |
| 18) 4.68 km = ___ m | 19) 0.056 mL = ___ kL |
| 20) 4.68 in = ____ km | 21) 153,689 mm = ___mi |
| 22) 65 mi/hr = ____ m/s | 23) 16 m/s = ___ mi/hr |

Convert into scientific notation.

| | |
|---|---|
| 24) 0.3 | 25) 54 |
| 26) 6,870,000 | 27) 0.000 000 000 006 08 |

Convert into standard notation.

| | |
|---|---|
| 28) $9.06 \times 10^{-9}$ | 29) $2.0 \times 10^{2}$ |
| 30) $8.235 \times 10^{11}$ | 31) $6.25 \times 10^{-2}$ |

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