# USING INQUIRY-BASED LAB ACTIVITIES TO INCREASE STUDENT INTEREST AND ACTIVE PARTICIPATION IN LEARNING SCIENCE

by

Jean Philip Christian Mathot

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Jean Philip Christian Mathot

June, 2009

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ABSTRACT

The purpose of the research project is to determine if inquiry-based labs increase student involvement and interest in science. Labs given at the middle school level are often of the cookbook variety. The step-by step format limits students' involvement in experimenting with their own ideas. Inquiry-based lab activities allow students more ownership and choice in the experimental design and implementation in doing the lab activities. Students were given three cookbook style labs and three inquiry-based labs over a three month period. Students receiving both lab types preferred inquiry-based over cookbook, felt they were more involved in the experiment and found them more interesting. Assessment results showed no significant difference in student understanding between the cookbook style and inquiry-based lab approaches. Teacher observations suggested that an inquiry-based approach resulted in greater student involvement and less student behavior concerns. An inquiry-based approach is an important comment, along with a cookbook style approach, for offering students a balanced science lab experience at the middle school level.

# INTRODUCTION

From the first day that children start their educational journey teachers have been there to help them answer the questions they do not know how to answer. Early on, educators give children some crayons, paper, glittery glue, scissors and the freedom to create whatever they want on those pieces of paper. As students move through the educational system, the crayons are replaced by pens and pencils, scissors and glue by textbooks. The teacher no longer says "create whatever you want," but tells the students to follow the directions and fill in the blanks. Somewhere along the way students learn that there is one best answer: the one that the teacher marks correct. The freedom to explore and imagine is not as prized as correct answers. School stops being a place of wonder and interest and instead becomes a place that requires following the directions to find the right answers. Students are increasingly directed towards shedding their drive to explore in exchange for papers that give them the directions on how to exactly do the work. Thinking "outside the box" has been squeezed from the classroom by the pressure placed on students to have the correct answers. It is important that students see that asking, "what if" and seeing "what happens" can be just as important as finding the right answers.

One of the more important goals of education is developing the love of learning in students. It is important to instill that they are life-long learners. This can happen if learning encourages students to explore, challenging them to answer their own questions that arise as they learn. Cookbook style labs do not seem to encourage a love for learning or challenge students to explore new ideas. The path the student takes has already been laid. All that is needed is for directions to be followed and post-lab questions to be answered. Inquiry-based lab activities move away from the pre-laid path and into the "what if" or "let me try this" mindset. That is the place where students need to be able to visit so they can really enjoy learning about and using science. These are the type of experiences that allow students to become life-long learners.

Many middle school lab activities are often of the cookbook variety. This step-by-step approach requires little thought nor encourages students to think of “what if” as they conduct and complete the assigned activity. It seems that students are more concerned with getting the right answer than exploring the possibilities for discovery. The thinking mind is turned off and the imagination to explore dimmed so that labs can walk the student to the correct results with neither risk, nor reward. The motivation and ability to explore is lost in the directions. The excitement and allure of thinking and testing the “what ifs” are quelled. Inquiry-based lab activities are the torch that reignites students’ interest in doing and exploring the world around them.

## FOCUS QUESTION

What is the impact inquiry-based lab activities have when they are used to teach physical science to eighth grade middle school students? The sub questions for this project are:

1. Do inquiry-based lab activities encourage student involvement and interest in doing science lab activities?
2. What is the impact of cookbook style lab activities compared to inquiry-based?
3. What is the nature of understanding and learning of inquiry-based labs?
4. What is the impact on the teacher when an inquiry-based lab approach is used?

## SUPPORT TEAM

I have selected three individuals to be my support team for my AR project. Two of the individuals are teachers that work with me at Sierra Vista Middle School in Irvine, CA. The third member of my support team is my father.

Kathy Marvin is an amazing science teacher at our school who also teaches physical science to 8th grade students. She is part of my support team because she has an amazing gift in developing curriculum, creating lessons that get students engaged in hands-on science, and teaching experience in inquiry based science.

Christina Ralston teaches language arts at our school. She is part of my support team to assist me with proof reading, including the grammar and format for my paper. She is very meticulous and will help to keep my paper professional and free from errors.

Last in my support team will be my dad Christian. He has a Ph.D in Physical Chemistry. He has published many papers in leading scientific journals and can advise me on what should and should not be part of my project paper.

Additional support and advice will come from Dr. Walt Woolbaugh and my project reader Dr. Jeff Adams.

## LITERATURE REVIEW

This section starts with a description of what inquiry is and what it looks like in the classroom. A review of the literature illustrates the benefits an inquiry-based approach brings to students learning science. These benefits to student understanding, learning, and motivation are discussed and referenced from past studies. A description of the more traditional cookbook lab approach is given along with the concerns that come along with this type of lab activity. Two published studies help to support the belief that students benefit from inquiry-based instruction. There are many positives that come from this approach, but some concerns mentioned in other studies are listed at the end of this section.

An understanding of inquiry-based science is necessary to understand how this approach teaches science in a more involved and meaningful way. Llewellyn (2002) defines inquiry as,

> "…the science, art, and spirit of imagination. It can be defined as the scientific process of active exploration by which we use critical, logical, and creative thinking skills to raise and engage in questions of personal interests" (p. 16).

Inquiry-based science is "hands-on, minds-on science exploration" (Humprhey, 1995). Students engaged in inquiry-based exhibit many of the following characteristics (Humprhey, 1995):

- Children view themselves as scientists in the process of learning.
- Children accept an "invitation to learn" and readily engage in the exploration process.
- Children plan and carry out investigations.
- Children communicate using a variety of methods.
- Children propose explanations and solutions and build a store of concepts.
- Children raise questions
- Children use observation.
- Children critique their own science practices.

Inquiry-based instruction begins with the formation of a question or introduction of a problem that needs to be solved. Students then develop a way to investigate or explore possible solutions that help answer the question or resolve the problem. Data are then collected and analyzed to help draw conclusions. This process is repeated until a connection can be formed between current understanding, new discoveries, and prior knowledge.

Problem-based learning (PBL) is an inquiry-based strategy that presents students with a problem that needs to be answered with experimentation and implementation. In this type of inquiry-based approach, students take responsibility for accessing information, developing hypothesis, collecting and using data to produce conclusions based on evidence and reasoning (Sungur & Tekkaya, 2006). According to Karabulut (2002), this type of learning creates an environment in which students actively participate in the learning process, initiate their own learning, learn time management skills, identify impediments to solving problems, and access resources. PBL improves critical thinking, communication, mutual respect, teamwork, interpersonal skills, and students' interest in science (Sungur & Tekkaya, 2006).

Students learn science by hearing, doing, and exploring concepts. Gerber, Cavallo, and Marek (2001) break down the three key components that allow students to learn science at school: exploration, term introduction, and concept application. In exploration, students participate in labs that allow them to test ideas, conduct experiments, and collect data. Term introduction expands student understanding of key concepts and ideas allowing them to better understand and utilize collected data. Concept application requires the student to use data to draw conclusions or to answer questions in other learning situations. An inquiry-based approach allows all three components to occur, which allows students to better learn and enjoy science.

Ancillary materials provided with science textbooks include a majority of labs that have step-by-step instructions (Peters, 2005). These lab activities are termed cookbook labs because students are given step-by step instructions (the recipe) to carry out the experiment to obtain the predetermined outcome (Volkmann & Abell, 2003). Lord and Orkwiszewski (2006) noted that the “cookbook” method is common in schools, but very little information is learned by students who plug in the results from the lab into the prepared lab questions.

Inquiry based labs have a far different outcome in student learning. Lord and Orkwiszewski (2006) claim, ”Inquiry learning instills higher understanding than simply following step-by-step instructions on a series of lab book pages” (p. 342). It seems that students are able to discuss what procedures to utilize, the controls and variables involved in the experiment and the formulation of valid conclusions (Marbach-Ad & Sokolove, 2000). Students need to be active participants in the learning process. By giving students step-by-step instructions, they are passively learning the material. If students are not given the opportunity to experience inquiry learning, they will mentally tune out, passively awaiting the end of class with little critical thinking taking place (Lord & Orkwiszewski, 2006).

Benefits of an inquiry-based approach have been observed in other studies. In 2003, Tretter conducted a study of 255 high school physical science students and found that the group exposed to inquiry-based labs were more engaged in the course throughout its duration, less likely to give up in the class (11% of inquiry students vs. 29% for non-inquiry), and their attitudes towards the study of physical science improved. A 2005 study by Sungur & Tekkaya involved 61 high school biology students exposed to a PBL or a traditional instructional approach. Those students that were taught using a PBL reported science as being more interesting, important, and useful compared to students instructed in the traditional teaching approach.

For more than a half century, there has been discussion on whether instructional based (cookbook) labs are better for increasing student learning and understanding compared to open inquiry-based (minimally guided) labs. Educators during the 1950s and 1960s suggested that students would learn best in an unguided or minimalist type environment (Mayer, 2004). This viewpoint has been put into practice by many educators, even though it may not always be the best method for student learning. Kirschner, Sweller, and Clark (2006) suggest that current knowledge of human cognitive architecture shows that minimally guided instruction is likely to be ineffective. They advocate for educators to stop using discovery type labs and implement activities that guide students through the experimental and learning process. Inquiry should not be geared towards throwing students into a lab activity, expecting them to know what they should explore or learn from the activity themselves. For an inquiry-based approach to be beneficial to student learning, educators must decide what the learning objectives are for the activity and how to best guide the students towards these learning outcomes.

Both cookbook and inquiry-based labs have their place in the science classroom. The concern is not which is the best method for doing lab activities; but which method engages students when conducting science activities, encourages students to try out ideas, and address their own questions that arise when immersed in learning science. Llewellyn (2002) describes inquiry learning as, "…empowering students with the skills and knowledge to become independent, lifelong learners that are accustomed to finding answers to their own problems through the process of discovery" (p. 10). Students that learn by this approach perceive science as more interesting, important, and useful. These beliefs are held by students that are taught using inquiry compared to a cookbook instructional approach (Tretter & Jones, 2003; Sungur & Tekkaya, 2006).

Research has shown the value and worth of inquiry-based instruction. Students are invited to become the scientist and see how science is really done. They are allowed to be active in their learning, instead of bystanders as with cookbook style labs. An inquiry-based approach allows students to develop a richer, deeper understanding of the concepts and materials they are learning (Smolleck & Yoder, 2006). Learning science requires interacting with the concepts and material on a personal level. A majority of this hands-on interaction is through cookbook style labs. Studies have shown that this type of lab approach alone may not be the most suitable for helping students to learn science or pique student interest in learning the material (Lord and Orkwiszewski, 2006). An inquiry-based approach may be a better instructional strategy to enhance student learning and interest in science (Tretter & Jones, (2003).

## TREATMENT

Eighth grade physical science students at Sierra Vista Middle School have historically been given hands-on, activity based instruction while learning chemistry and matter. There is an average of one lab activity per week during this unit of study. Students are generally placed in groups of four or five and share the same lab equipment and lab space while working on the lab activities. The majority of these lab activities are of the cookbook variety because specific directions help ensure the safe usage of chemicals. These labs usually require one to two days to complete. One of the drawbacks of the cookbook lab approach is the small number of students actively engaged in doing the lab or experimentation in each lab group. One or two students are involved in getting the chemicals, adding them together, and utilizing the equipment while the other two or three students sit and wait. This does not allow the majority of the students to be engaged in doing the experimental part of the lab.

Inquiry-based labs, those labs that allow students more latitude in the experimental design and data collection methods, have not historically been used in the study of chemistry because of the need for a safe lab experience. The inquiry-based labs in this study were designed to allow students to participate safely and actively in the experimental part of the lab. All of the labs were designed by the teacher, with the goal of covering the science curriculum in a hands-on, lab-based approach. The labs were inspired or influenced by labs done in middle school (*I Hope it Floats*), interesting chemical reactions found in science textbooks (*The Making of Silver and Falling Snow*) or online, and from demonstrations by professors at the university level (*Sublime Lab*). The lab write-ups were written and designed by the teacher and were not modified labs taken from science textbooks. The inquiry-based labs were also designed to engage students into thinking and reasoning at a higher level. In the cookbook style labs, students are told exactly what they need, and use very little thinking or their own science intuition. When the responsibility for designing and measuring the experiment falls to students, the interest level of the students may increase.

Table I. Pretreatment and Treatment Labs

| Treatment Labs | Inquiry-Based | Duration | Science Content |
|---|---|---|---|
| SK8 Motion Lab* | Yes | 5 Days | Speed, velocity, acceleration, friction, time, distance, motion |
| Hot Wheels Motion Lab* | No | 1 Day | Speed, velocity, acceleration, friction, time, distance, motion |
| Sublime Lab | Yes | 1 Day | Sublimation, phase change, the states of matter (solid, liquid, gas) |
| Amorphous Blob Lab | Yes | 1 Day | Amorphous solid, crystalline solid (NaCl), polymers, the states of matter (solid, liquid, gas) |
| Exo/Endothermic Lab | No | 1 Day | Endothermic, exothermic, decomposition reactions, reactants, products, heat, conservation of matter |
| Making Silver & Falling Snow Lab | No | 1 Day | Chemical reactions, reactants, products, solutes, solution, concentration, precipitate |
| I Hope it Floats Lab | No | 5 Days | Density, buoyancy, buoyant force, displacement, surface area, mass, volume |
| Build a Boat Lab | Yes | 5 Days | Density, buoyancy, buoyant force, displacement, surface area, mass, volume |

** SK8 Motion and Hot Wheels Motion Lab were pretreatment test labs*

Prior to the administration of the six treatment labs (Table I), of which three were inquiry-based and three were of the cookbook variety, there were two pretreatment test labs given to students in the study. The *SK8 Motion Lab* and *Hot Wheels Motion Lab* (Appendix E) were given to see how students would respond to an inquiry-based lab and an equivalent cookbook style lab. The *SK8 Motion Lab* allowed students to experience the format of an inquiry-based lab, compared to the traditional labs that they had experienced in past science classes. The *SK8 Motion Lab* was used to gauge how the treatment labs should be presented and the amount of challenges that would be appropriate for future inquiry-based labs. The *Hot Wheels Motion Lab* represented the cookbook approach and covered similar physics content to that covered in the *SK8 Motion Lab*.

A total of six physical science lab activities were used in this research project. These lab activities were conducted by students over a four month period commencing in January 2009 and ending in April 2009. Each of the first four lab treatments took one class period (50 minutes) to administer and complete. The last two lab treatments each required one week (five 50 minutes classes). There were three cookbook style labs and three inquiry-based labs. The six labs, plus two pretreatment test labs, were given to the two other eighth grade physical science teachers at the school for peer review to help establish validity and reliability. The six labs were determined to be comparable in the scope of material covered, state standards addressed (Appendix D), the time needed for completion, and the difficulty level required to conduct and complete the labs. They differed mainly in their format, cookbook versus inquiry-based. The labs explored concepts in chemistry, specifically the three states of matter; the unique properties of matter in the different phases; chemical reactions with a look at reactants and products; and finally the relationship between surface area, buoyancy, density of matter and how that affects objects that are placed in water.

The *Sublime Lab* (Appendix F) was the first of three inquiry-based lab treatments given to the students. The Sublime Lab has students explore dry ice and phase change, specifically sublimation. Each lab group, each containing three to four students, was given a quantity of dry ice and lab equipment for conducting experiments and recording observations. Students were asked to design a research question and conduct three experiments incorporating the dry ice and its ability to sublime. They recorded their experimental design, observations, and any data collected into their notebook. Using the notes, sketches, and recorded observations, students were asked to address their research question, explain what was happening with the dry ice, and why. They were also encouraged to list any questions or observations they did not understand in their science notebooks. The final step was for them to write down what they learned or discovered in exploration of dry ice. The *Sublime Lab* was an example of an open-inquiry based lab activity because it required students to develop their own research question and the experimental design to answer the question. The lab took one class period (50 minutes) to administer and complete.

The *Amorphous Blob Lab* (Appendix F) was the second inquiry-based lab treatment given to students; they explored the characteristics of solids and liquids by using an amorphous solid. The lab activity challenged students to determine if a mixture of water and cornstarch is a solid or a liquid. Students were asked to experiment and play with the mixture and record any observations and characteristics of the matter they created. Students sketched pictures of the activity, recorded characteristics, and listed observations in their notebook as they worked with the material. They were to determine if the matter they created was a solid or a liquid and to give a minimum of three reasons for their belief. The last part of the lab activity asked them to justify why a glass bottle full of salt is a solid and not a liquid, even though the salt pours much like a liquid pours. The *Amorphous Blob Lab* was an example of a PBL because it asked students to prove the state of matter they created. The lab took one class period (50 minutes) to administer and complete.

The two cookbook style labs were administered approximately two weeks after the two inquiry-based labs above were completed. The *Exothermic/Endothermic Lab* (Appendix G) was the first cookbook style lab given to the students. This lab had students conducting one exothermic and one endothermic chemical reaction by mixing two different salts (KCl and $CaCl_2$) in water and recording the temperature change over a period of one minute. The lab supplied the students with the step-by-step procedures, a data tablet, and post-lab questions that were answered after the completion of the lab activity. The lab took one class period (50 minutes) to administer and complete.

The *Making of Silver and Falling Snow* (Appendix G) was the second cookbook style lab given to the students approximately one week after the first cookbook style lab. The focus of this lab was on diluted versus concentrated solutions and the formation of products in a chemical reaction. Students created a diluted and a concentrated $AgNO_3$ solution and added a piece of cooper wire to each solution. Over a period of ten to fifteen minutes they observed the single replacement reaction and formation of silver on the copper wire. Post-lab questions were answered after the reactions had proceeded for at least ten minutes. The second part of this lab focused on the formation of a saturated solution and the parts of a solution, the solute and the solvent. After the lab, students answered questions based on the newly formed solution and its solubility and concentration. The lab took one class period (50 minutes) to administer and complete.

Two final treatment labs, for a total of six labs, were given a month after the other four labs were administered. The timing reflected the curriculum sequence, not a specific design of this research project. There are three main differences with these two treatment labs compared with the first four. First, the cookbook style lab was administered prior to the inquiry-based lab, which is opposite the ordering of the other four lab treatments. Second, the last two lab treatments are very similar to the topics they had the students explore - buoyancy, surface area, displacement, and density - since they both had students create a boat. The final difference is that the group size for these final two lab activities was two to three students per group instead of the three to five students for the first four labs.

The *I Hope it Floats Lab* (Appendix G) was the cookbook style lab given over a four day period during the last part of March 2009. The lab activity required students to strictly follow the seven steps of the scientific method as they built a boat out of aluminum foil. Students had an opportunity to design, build, test, and record data on how much cargo (trash) each boat design could float before sinking. The lab required one week (five 50 minute classes) to administer and complete.

The following week students were given the inquiry-based lab treatment with the *Build a Boat* (Appendix F) lab activity. This lab required students to build a boat out of any material they selected as long as the boat did not have a mass greater than 40 grams and was no larger than 50 cm x 36 cm. Students did not need to follow all seven steps of the scientific method, but were required to keep a daily science journal of what they did, learned, collected, and uncovered each day about their boat and the process of creating a boat. They were given five days to create, test, redesign and produce a boat that could hold the maximum amount of weight, while staying within the lab activity stated requirements. The *Build a Boat Lab* was an example of an inquiry-based lab activity with both open-inquiry and PBL components. The lab required one week (five 50 min classes) to administer and complete.

These six lab treatments allowed students the opportunity to learn science using a hands-on approach but with significantly different methods for having students learn the material. During the study a number of methods were used to determine which treatment was best able to generate interest and involvement by students learning science.

## METHODS

Students were introduced in early Fall 2008 to lab activities that had an inquiry-based approach. These inquiry-based labs set the foundation for the new approach in which many of the students had not been exposed to prior to eighth grade science. Most students had completed lab activities that were of the cookbook lab approach until this point.

### *Participants*

This study was conducted during the 2008-2009 school year involving eighth grade middle school students attending Sierra Vista Middle School in Irvine, California. The school has a population of approximately 1,000 seventh and eighth grade students, of which 140 eighth graders were included in this study. There were five sections of eighth grade physical science, with each period having 32 to 35 students per class. The student population is majority Caucasian followed closely by students of Asian descent. There are a few Persian, Latino, and Afro-American students. Approximately two percent of the student population participates in the reduced or free lunch program.

The participants in the study range in age from 12-14 years old and are almost equally divided between male and female. Each of the 140 students in the study completed the six lab treatments that began in the January 2009 and finished in April 2009. Most of the students have had science lab experience in the classroom prior to eighth grade physical science. Most are currently taking algebra, with five percent taking geometry at Northwood High School in Irvine. Generally, the students are highly motivated to do well in school and come from middle to upper socioeconomic status. Most of them complete their work on time and the majority of students have done well on previous lab assignments. Parent support and emphasis on education are strong at the school and throughout the district.

*Instruments*

Several methods were used to measure student attitudes and interest levels towards inquiry-based lab activities and to see if these lab activities increased student involvement and interest in doing the labs. An overview of the methods used to collect data for the research project is described in Table II and a timeline for implementation for each is outlined in Table III. To help ensure validity, all lab treatments, student interview questions and attitude surveys were peer reviewed by the five science teachers at the school.

Table II. Methods for Data Collection

| Research Questions | Methods | | |
|---|---|---|---|
| | 1 | 2 | 3 |
| 1. Do inquiry-based lab activities encourage student involvement and interest in doing science lab activities? | Likert Attitude Survey | Student Interviews | Teacher Observations |
| 2. What is the impact of cookbook style lab activities compared to inquiry-based? | Likert Attitude Survey | Student Interviews | Teacher Observations |
| 3. What is the impact on understanding and learning of inquiry-based labs? | Student Notebooks | Cookbook vs. Inquiry Assessment | IOLA Pre-Test and Post-Test |
| 4. What is the impact on the teacher when an inquiry-based lab approach is used? | Teacher Observations | Student Notebooks | Teacher Reflection |

Table III. Timeline for Data Collection

| Data Collection Technique | Timeline |
|---|---|
| 1. Likert Attitude Survey (Pre) | October 2008 - Early first trimester |
| 2. Likert Attitude Survey (Post) | April 2009 - After all six labs treatments |
| 3. Student Interviews | April 2009 |
| 4. Student Lab Reports | Late April 2009 |
| 5. Teacher Observations | Fall 2008 - Spring 2009 |
| 6. IOLA Standardized Tests | January 2009 - May 2009 |
| 7. Cookbook vs. Inquiry Assessment | June 2009 |

The first data collection instrument used in this study was a pre-treatment Likert Student Attitude Survey (Appendix A) that was administered October 2008 to each student (*n=140*) in five physical science classes. It consisted of 17 questions that asked students to gauge their feelings towards science, lab activities, and how they best felt they learned science. The survey asked students to select their preference for lab activities that told them exactly what to do versus labs that allowed them choices in finding the best way to carry out the activity. It also asked the students how they best felt they learned (hands-on vs. textbooks and worksheets). Students were also asked what they most enjoyed about science lab activities. The survey concluded with three open response questions. The questions asked about the usefulness of lab activities in understanding science. The survey concluded with the opportunity for students to suggest what they felt could be done to make lab activities more interesting.

Students were given a post-treatment Likert Attitude Survey (Appendix A) in April 2009, six months later, after receiving all six treatment labs. This post-treatment attitude survey consisted of 25 questions: the first half of the survey asked students to gauge their feelings towards science, lab activities, and how they best felt they learned science. The second half of this survey focused specifically on the lab treatments in this study. Students were asked to compare the labs and their interest and involvement in the lab activities.

Twenty percent of the students, six students from five separate classes, for a total of 30 students, were interviewed for further insight into how the labs affected their interest and participation in learning science. Students were selected using a stratified random sampling in which ten randomly selected students from the low group (79% and below grade average), ten from the midrange group (80% to 89% grade average) and ten from the high group (90% and above grade average). Two students, both from the same grade level grouping, were interviewed at a time. The students were asked which lab activities during the year were their favorites, which allowed them to be most involved in the experimental process, and which were the most interesting. The interview questions (Appendix C) also focused on how they performed the labs. They were asked if they preferred labs that gave specific step-by-step directions compared to ones that allowed more student direction and decision-making in completing the experiment. Students were then asked to if they preferred having to answer post-lab questions (commonly found in cookbook style labs), compared to keeping an active science journal, that includes inquiry-based lab activities, observations, data, experimental design, and reflections of what they learned or wanted to test while during the lab activity. Students were also asked to compare the lab experience this year with science labs performed the prior year. The responses from these interviews were used to acquire evidence to whether or not the labs are increasing student involvement, participation and interest in learning science and how students felt they learned best.

Student involvement and participation were observed informally by the teacher during the lab activities. At the end of each class period, two to five observations were written down into a notebook kept by the teacher. These notes described the general activity and interest level of the students, number of students engaged in the lab, number of students passively sitting while other group members worked, and how often students had to be encouraged to engage in the lab. There was no formal rubric used for evaluation. The nature of the labs required continual teacher assistance in: delivery of chemicals and supplies, setup of lab equipment, helping individual students, and assessing student work. There was little time available for recording formal observations. The observations that were made were used to reflect upon the study questions that focused on student involvement and interest in doing the labs. These teacher observations helped illustrate student behavior during these lab treatments from the teacher's perspective and as a record of the perceived interest and involvement of the students in conducting the labs. The notes were used to develop questions for student interviews and to reflect upon inquiry-based lab activities as an important and enjoyable teaching tool.

Student science notebooks were used to study the impact on understanding and learning by students while conducting the inquiry-based lab activities. Each of the cookbook style lab entries were compared to the inquiry-based lab activities. The notebooks were checked for completeness, quality, effort, evidence of connections to the science content, and the depth of information recorded. Each treatment lab outlined the notebook requirements for the lab activity. The rubric used to grade and evaluate the notebooks focused on student effort and ability to take something away from the lab activity (Appendix H). There were a total of 30 notebooks, six from each class. Selection was made the same way student interview selection was conducted.

District mandated standardized tests were used to assess student learning and understanding of the standards covered by the treatment labs. The tests were created by science teachers in the district and are used at all the middle schools to assess student learning of the California State Science Standards. Each student completed the IOLA (Irvine On-Line Assessment) district standardized pre- and post-test. The first test covered the chemistry unit and the second covered the density and buoyancy unit. The exact same test was used as the pre-and post-test. The results of the test were used to show that students increased their understanding of the key concepts after being exposed to the lab treatments. The results do not differentiate between which treatment was responsible for the increase between the pre-test and post-test scores. The post-test scores were compared to that of another teacher at the school that used a non-inquiry-based approach to teaching. A significant difference between the two groups was that this group did not receive the pre-test as did the inquiry-based group. The teaching styles of the two teachers are different in approach, but the content covered was similar. The non-inquiry-based group received a large portion of their instruction from worksheets, lecture notes, and the textbook. This group had limited exposure to lab activities compared to the inquiry group.

A cookbook vs. inquiry assessment was the final instrument used to measure student understanding. The assessments were administered in class during the first week of June 2009, more than seven weeks after the treatment labs were administered. Students were not given advance notice of the test or allowed to study the material prior to taking the assessments. Each of the two tests contained 10 questions (Appendix I), questions that were specific to each lab and the subject matter covered. Results for the two tests were used to see if there were any significant differences in student understand of the science material.

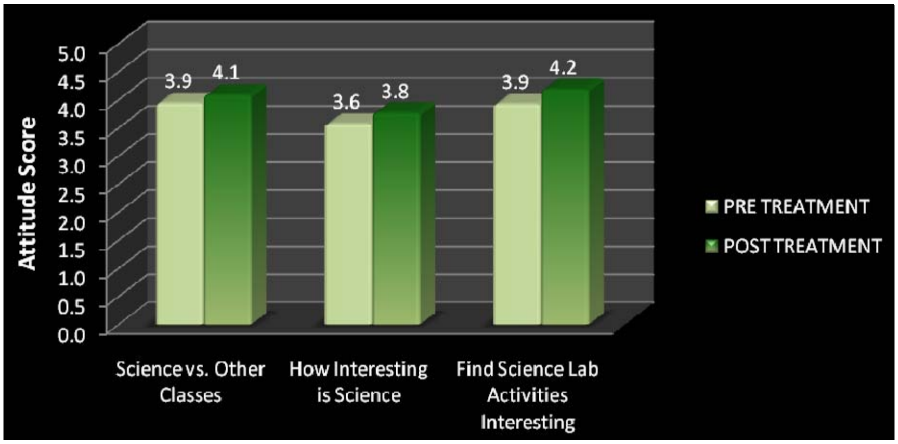
## DATA ANALYSIS

The analysis of the data collected focused on addressing the impact inquiry-based lab activities had on student interest and involvement in doing science. The pre-treatment and post-treatment surveys, along with student interviews, addressed how student attitudes and involvement in science were affected by the introduction of inquiry-based labs. These instruments also helped to see if cookbook style labs bore students and if they excluded some from doing the experiment and being actively involved. Review of student lab notebooks allowed for comparison between the two approaches, charting the depth at which students were engaged in the material. Teacher observations helped support results from the fore mentioned instruments and addressed the impact on the teacher with this type of teaching approach.

### *Attitudes Towards Science*

Students were asked how science compared to their other classes, how interesting they found science, and how interesting they found science lab activities. A comparison of both the pre- and post-survey responses is shown in Figure 1.

Figure 1: (Likert Attitude Survey Results – Attitudes Towards Science)




*Student (n=140) responses for pre- vs. post-treatment.*
*Q1 (1=Hate it, 2=Near the bottom, 3=In the middle, 4=Near the top, 5=My favorite class)*
*Q2 & Q3 (1=Not at all, 2=Very Little, 3=Somewhat, 4=Very Interesting, 5=Extremely Interesting)*

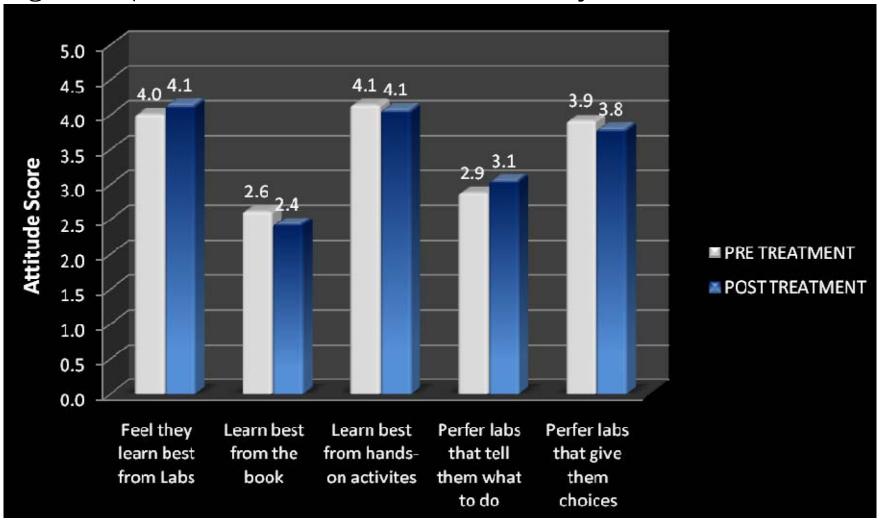
The majority of student responses (61%) thought science was very or extremely interesting. Almost all students (99%) thought science was at least somewhat interesting. Students selected science near the top (85%) compared to the other classes they are currently taking. Students that were interviewed mentioned the labs, demonstrations, and projects as what they most enjoyed about the class and why it is one of their favorite classes. One student said, " I really like having all the demos in class. They help me to understand what we are learning and the new vocab we were learning. The labs also help so I could do the stuff after seeing it happen in class."   Those students that did not rank science as one they liked said it was because they did not find the material or science interesting or they never do well in science. Student interest in science and doing science activities was high, but their attitudes towards science did not change significantly as a result of the six treatment labs. This was confirmed using a *t-test* comparing the means from the pre- and post-surveys. The lack of a significant increase in interest over the course of the treatment may be a result of the already high interest at the start of the study.

The one area where there was a difference after the treatment was that students found the actual science lab activities more interesting. A *t-test* was used to compare means and confirm that there was a significant difference *($p=.02$).* The majority of these students found lab activities very or extremely interesting (86%) post-treatment. The pre-treatment number was lower (74%). A few students (14%) thought the labs were only somewhat interesting after completion of the treatment labs, but was lower than the number prior to doing the labs (21%). The significant impact on students from doing the lab activities is that almost all students (94%) found $8^{th}$ grade science labs more interesting than the labs they conducted in $7^{th}$ grade. A student that was interviewed said this about the chemistry labs, "We got to mix chemicals together and see something being made. We actually got to make something and see something happen. That was really cool." The reason for this seems to be two fold. First, students that were interviewed explained that they enjoyed learning about physics and chemistry more than biology and health. Second, there were more lab activities and higher involvement compared to last year. One student explained, "We only had a few labs last year and they were not that fun. There are a lot more labs this year and they are a lot more interesting."

### *Attitudes Towards Learning*

The Likert attitude surveys looked at how students felt they best learned science and the type of lab approach they preferred. A comparison of both pre and post survey responses is shown in Figure 2.

Figure 2: (Pre and Post Likert Attitude Survey Results – Attitudes Towards Learning)

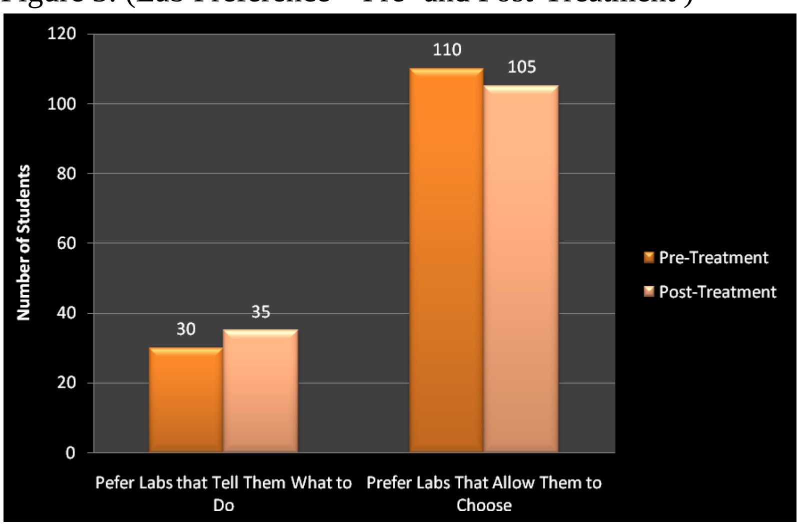



*Student (n=140) responses for pre vs. post-treatment Likert attitude survey. (1=Disagree, 2=Not Really, 3=Sometimes, 4=Agree, 5=Strongly Agree)*

Student attitudes towards how they felt they learned best did not change significantly nor did their preference for cookbook style labs or inquiry-based labs as a result of the treatment. The results suggest that students felt they learn best when doing hands-on and lab based science activities, compared to reading the textbook or completing worksheets. Interviews with students *(n=30)* revealed that many students thought the teacher demonstrations were as important as doing the hands-on activities in learning and understanding science. This is possibly because teacher demos are accompanied by an explanation of what is happening and why. When students are doing labs on their own, not everything is known by the student. This causes some students to worry about not understanding why or what they should be focused on learning. One student explained, "With demos you get to see the cool experiments and then are told how or why they work. When you have to do labs, sometimes you do not know why for sure stuff happens or how to make it work all the time."

Exposure to inquiry-based labs did not result in an increase in the number of students who preferred labs activities that gave them choices in how to conduct the lab (Figure 3). Prior to the treatment labs, 110 students (79%) preferred labs that allowed them choices compared to 30 students (21%) that preferred labs that told then exactly what to do. After doing the treatment labs, student preference dropped slightly for labs that gave them choices (75%) and rose for labs that told them exactly what to do (25%). A *t-test* analysis showed the difference *(p=.6)* was not significant. Of the 140 students, 40 students switched their preference. Of those that switched to labs that allowed them to choose, 16 of the 17 students (94%) in this group had a B average or above in the class. Of those that switched to labs that told them what to do, 11 of the 22 students (50%) in this group had a C average or lower. A possible reason for students with lower grades changing preference might be that they benefit from and need the structure and the guidance found in cookbook labs. The inquiry-based labs required them to take more responsibility for the learning, which many in this group are not accustomed to doing.

Figure 3: (Lab Preference – Pre- and Post-Treatment )

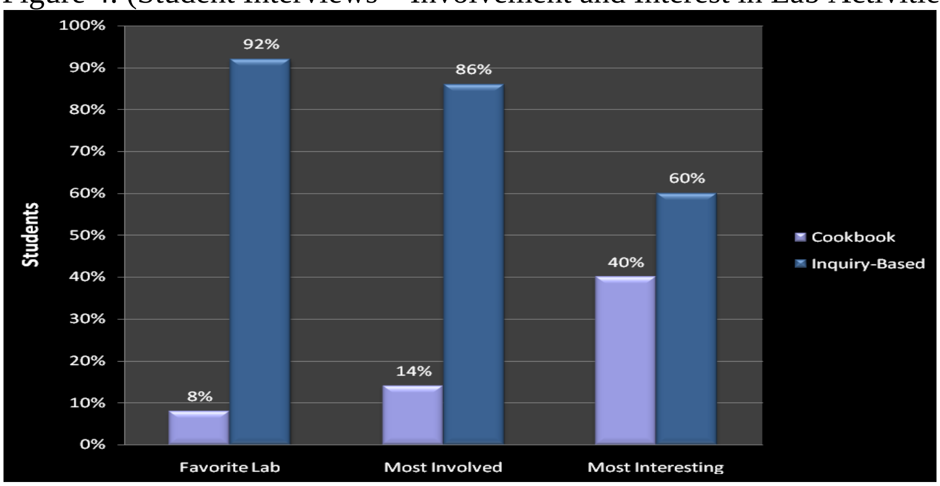



*(n=140)*

*Involvement and Interest in Lab Activities*

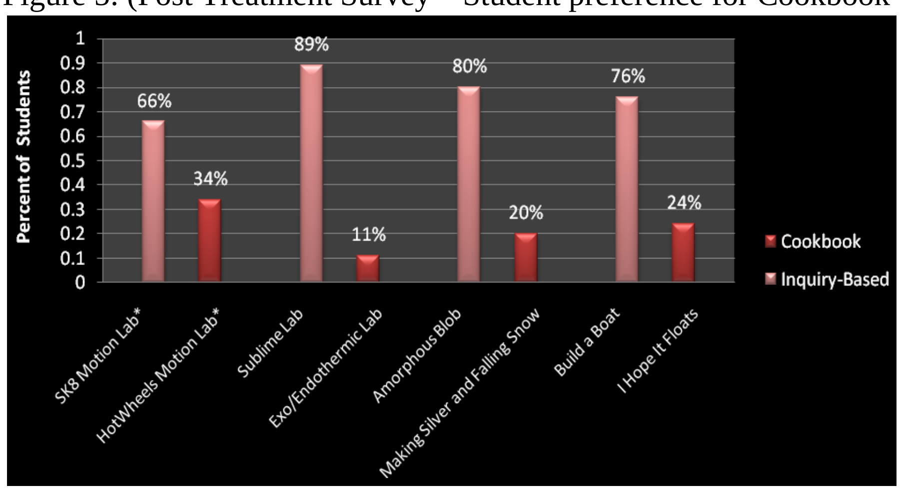
The main hypothesis for this research project was that inquiry-based lab activities would allow students to be more involved and would increase interest in doing science compared to cookbook style labs. Student interviews were used to gauge student involvement in the treatment labs. The student attitude post-treatment survey was also used to see which labs were preferred by students. A comparison between cookbook style labs and inquiry-based lab preferences is shown in Figure 4 for student interviews and Figure 5 for the post-treatment survey responses.

Figure 4: (Student Interviews – Involvement and Interest in Lab Activities)




*Student preference for lab treatment type: Cookbook vs. Inquiry-Based Labs (n=140)*

Figure 5: (Post Treatment Survey – Student preference for Cookbook vs. Inquiry–Based Labs)




**(SK8 Motion and Hot Wheels Motion Labs were pretreatment test labs) (n=140)*

Students overwhelmingly selected the inquiry-based over the cookbook style treatment labs as being their favorite (92%). In addition to being the preferred lab approach students also felt they were more involved (86%). The inquiry-based labs were more interesting (60%) compared to the cookbook style labs. Student interviews shed light on why there was such a heavy preference. A majority of the students that participated in the interviews and selected one of the three inquiry labs as their favorite said it was because of the freedom to choose and explore. They felt they were able to make or play with something and they could use their own ideas. One student explained, “I like having the labs with a challenge. I have to use my imagination to solve the problem and I like doing that type of stuff.” Another student commented on the Build a Boat lab by saying, “It is fun to build and test and learn what works. If it does not work you can always go back with a friend’s help and make it work with what you learned.” In most other classes students do not get a chance to choose. They come to science class and it is hands-on. Not only is it hands-on, but the teacher is asking the students to be the experts, to decide how they want to approach a problem or question. Students enjoy being challenged, if for no other reason than to prove that they can do it. One student mentioned that it was a matter of pride for him to be able to solve the challenge and do well in the lab. Students also enjoyed creating and seeing what happens, especially when it is something they have been a part of making. This might be the reason students prefer the inquiry-based labs. These labs allow students to do the things that they normally do not get to do in the classroom. A few students shared the sentiment of one of the students interviewed when he said, “We got to make a boat and had to make it so it could hold a lot of weight. If it didn’t work we had to go back and make it work. When we got it to work we felt good about succeeding and getting a good grade.”

Student involvement and interest seems to increase when inquiry-based labs are used. There are a few possible reasons. First, inquiry-based lab activities averaged two to four students per group. The cookbook style labs averaged three to five students in this study. The smaller group size means that each student needs to be more involved and cannot just allow the others to do the majority of the work. Second, each student must address the challenge and they can only do that by understanding and doing the lab activity. The lab invites them to try to develop and carry out experiments that they think will address the challenge of the lab. Finally, materials they get to experiment with or create are interesting. In the inquiry-based labs they are given dry ice, cornstarch, and water to explore or even a skateboard to ride. With the Build a Boat a Lab they are able to build a boat that floats and is dependent on how well they perform in meeting the challenge. Interest is sparked because it is challenging; when they meet success it makes them feel like they really accomplished something.

The interviews revealed that almost half of the thirty students interviewed selected Build a Boat as their favorite because it had the highest level of involvement. Most students who selected this lab said, "It was the lab I felt most involved in doing the experiment and it was fun making a boat and trying to make it do better each time you worked on it". The post-survey supported the belief that inquiry labs would be preferred over cookbook labs. Each of the three inquiry labs were preferred over the three cookbook style labs. This was also true for the SK8 Motion lab compared to the Hot Wheels Motion lab. These two labs were pretreatment test labs used to introduce students to an inquiry-based lab approach. Preference for the inquiry-based labs might lay in the hands-on approach and the opportunity for freedom in the experiment. A majority of the students said that they preferred having the freedom to choose and the ability to use their imagination. One student said, "I enjoyed Build a Boat because if you fail you could go back and redesign and try again." Setting kids up to find success is possibly motivating them to enjoy learning science.

*Interest Level of Cookbook Labs*

A hypothesis in this study was that cookbook labs bored students. This was based mainly on teacher observation and the engagement level of students. Student interviews dispelled this notion. Of all the students interviewed *(n=30)* none of the students felt these labs were boring (100%). Students believed that all labs, treatment and non-treatment, had been interesting and enjoyable. However, the design of these cookbook labs is atypical. First, they are not taken from the book. All the labs have been created with student interest in mind. Second, they all have the goal of being interesting and producing something unique or cool. *The Making of Silver and Falling Snow* was perceived as being one of the most interesting of the cookbook style labs. Students really enjoyed making silver and having crystals form on the copper wire. One student explained, "It was a cool lab because you made something that was unexpected and that was cool." Another student mentioned a cookbook style lab that was not included in the set of treatment labs as being her favorite and most interesting. She said, "I like the *I Got Worms and So Do You* lab and the *Slime All Over* labs because you got to make something you could keep and take home." It is this "cool" factor and the creating of something different that allowed the cookbook labs in this project to be interesting for the students.

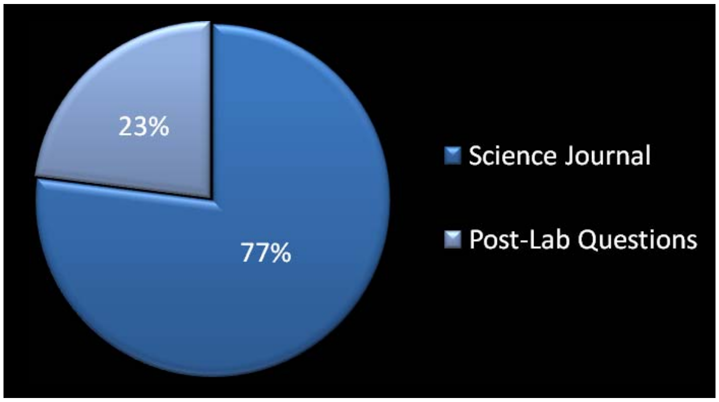
It was also predicted that cookbook labs exclude some students from being involved in the lab activity. Student interviews once again dispelled this teacher belief. Observations by the teacher tended to show that one to two students did the majority of lab work when cookbook style labs were conducted. This was especially true when doing the chemistry labs that required getting and mixing chemicals. A majority (75%) of the students explained that they took turns doing the labs or getting the chemicals. They felt that they were in fact engaged in the lab activities and did not have to be the one getting and mixing the chemicals to still be involved. The other quarter felt they were the one usually getting and doing the experiments, but felt that other group members helped as well. The above view points were not related to student academic performance level, but consistent between the entire range of academic performance. A reason for this discrepancy between teacher and student might have it roots in teacher perception and bias towards those students who do not appear to be working. It might also be that students might have a different idea of what is considered working compared to the teacher.

*Post-Lab Questions vs. Journals*

Prior to the student interviews, little attention was given to the difference in student responses to questions in cookbook versus inquiry-based lab activities. The most significant finding in this project came from the interview question that asked students if they preferred doing post-lab questions or keeping a science journal for writing reflections on the experimental process and collected data.

The two approaches were used in the treatment labs depending if a cookbook style or inquiry-based approach was used. Cookbook style labs tend to culminate with five to ten post-lab questions that are answered once the experiment is completed. The post-lab questions focus students' attention to the results of the experiment and help students make connections to key concepts explored in the experiment. The inquiry-based labs in this project tend to require students to write in their science notebooks. Students write in these notebooks describing the experimental design, observations, data collected, possible ideas or solutions, and a reflective piece on what they learned. Students writing in journals are using these written responses in place of the post-lab questions that conclude the cookbook labs. A comparison between post-lab and science journal student preference is shown in Figure 6.

Figure 6: (Student Interview – Post-Lab Questions vs. Science Journal)




Student (n=30) interview responses for lab write-up preference.

*"Do you prefer lab activities that have post-lab questions to answers or lab activities that have you do a science journal for writing your data, observations and what you learned?"*

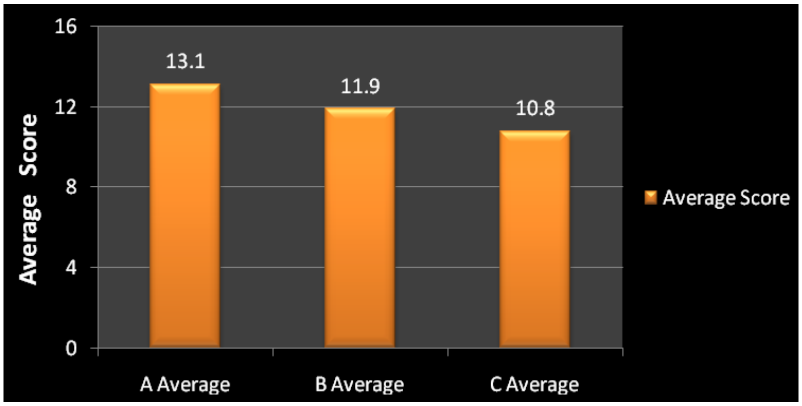
Each of the interviewed students was asked which approach he or she preferred. The majority of students preferred the science journal compared to answering post-lab questions (77%).  Students enjoyed the freedom to write down their own thoughts and reflections as they worked on the lab activity. They also felt the journal allowed them to write without the worry of being right or wrong.  Some students even said they liked how they could revisit, redo, or rewrite responses in the notebook.  One student explained, "It is dynamic. You can write in it and see your growth and progress."  Another said, "It allows me to see my step-by-step approach and see my mistakes. I can always go back and redo that part of the lab." A few thought the ability to reflect on what was done and learned was why they preferred this approach.

The majority of those that preferred the post-lab questions also enjoyed the science journal approach. They said they preferred the post-lab questions because the questions helped to prepare for the test and focus their studies on the most important ideas in the lab activity. Two students, both from the lower grade average group, preferred the post-lab questions because they were easier to answer than the science journal.

The interviews suggested that students liked the personalization available in the science notebook. There seems to be a sense of ownership and independence since they can choose what to include for each lab. It goes along with the justification that a journal gives them more freedom to decide what to write. This allows for the science they are doing in class to become a more personal, meaningful experience. One student explained, “I prefer the science journal because I get to decide what is important to write down and not just have to answer the post-lab questions. I like the freedom to write down what I am learning as I do the lab.” The one caution here is that students may like the notebooks because there is no real minimum for what they must include. They could use this as a way to do less work compared to the set amount of work that post-lab questions create. Another problem is that students were not given a science notebook grading rubric prior to the lab treatments. This oversight caused many students not to realize the expectations envisioned for each lab activity.

A look at student notebooks helped determine the extent and depth of student understanding and involvement in the science aspect of the inquiry labs. A total of 30 notebooks were collected and scored using a grading rubric (Appendix H). It should be noted that a total of 36 notebooks were collected in all. Six of the notebooks were not used because the students wrote so little or nothing at all; therefore, they could not be graded. These six students would have been in the lowest group. There was a significant difference ($p=.02$) between the highest grade group (A students) and the middle group (B students) and a significant difference ($p=.02$) between the highest group versus the lowest group (C and below students). There was not a significant difference between the middle (B students) and lower (C and below students) groups. Average scores for each group can be seen in Figure 7.

Figure 7: (Student Notebook Scores)



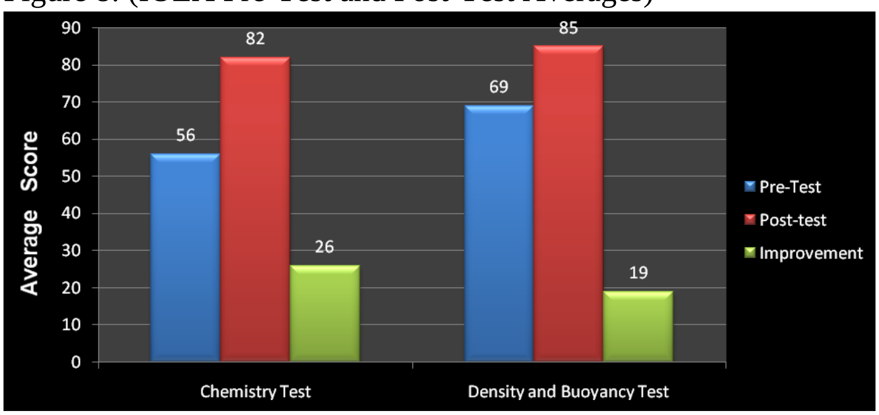

*Scores range from 0-16 and are based on 30 notebooks (n=30)*

Students in the higher grouped tended to have more elaborate and complete journal entries. Data was more clearly presented, detailed observations, reflections, and conclusions were more evident compared to the other two groups. Scores overall were lower than what had been expected. The reason for this might be that students were not shown a grading rubric prior to doing the labs. Students did not have an understanding of the depth or amount of writing needed to be included in the science notebook. Another possible reason is that students did not take the time to write in the journal as often as was expected. The hope was that students would be entering into the journal as they worked or at the very least, the end of each class period. The problem here is two-fold. First, students were so engaged in the activity that they did not leave themselves time to write in the notebook during the class period. Second, the *Amorphous Blob Lab* did not allow them to write in their notebooks at all because of the messy nature of the material they were using. It was impractical to try and write while hands were covered with water and cornstarch.

*Standardized Test Results*

The scores on the district created IOLA pre-test and post-test show that students significantly increased their understanding of the material and concepts ($p=.001$). The pre-test and post-test mean scores for chemistry and density and buoyancy are shown in Figure 8. There was a 26 point average increase on the chemistry test and a 19 point average increase on the density and buoyancy test. The increase suggests that students understanding and knowledge increased during the treatment, but does not offer insight into which lab approach was most instrumental in the increase.

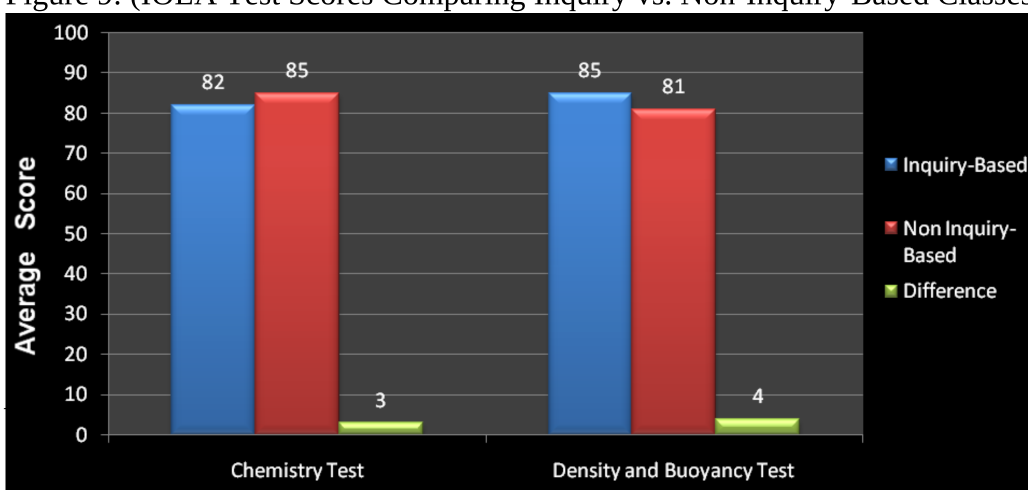
Figure 8: (IOLA Pre-Test and Post-Test Averages)




*Student Average IOLA scores for Pre-Test and Post-Test (n=140)*

Scores from the inquiry-based classes were compared to the mean scores from four 8$^{th}$ grade physical science classes (n=140) at the school. The teacher of these classes did not use inquiry-based methods, but utilized a more textbook and lecture driven approach. These IOLA test scores (Figure 9) showed a lower overall mean for the inquiry group on the chemistry test (82) compared to the non-inquiry-based comparison classes (85), although this difference was not statistically significant ($p=.2$). The mean scores for the density and buoyancy test did not show a significant difference either ($p=.09$). The inquiry-based students had a higher average mean (85) compared to the non inquiry-based group (81). A possible reason for the differences may be in the IOLA test themselves. The chemistry test is more fact and memorization based, where as the density and buoyancy test has more application type questions that deal with density and the ability to predict whether or not objects will sink or float in water. The later would better suit students that were exposed to a hands-on, inquiry-based approach compared to a more traditional lecture and textbook lessons. Another difference could be attributed to the use of the same test for both pre- and post-tests.  This might have allowed the inquiry group to score better because they would have had already taken the test prior to the post-test. The non-inquiry group would not have had this benefit of seeing the pre-test. Both the inquiry-based science classes and the non-inquiry based classroom had a student grade average for the term in the mid "B" range and were not significantly different (*p=.3*).

Figure 9: (IOLA Test Scores Comparing Inquiry vs. Non-Inquiry-Based Classes)

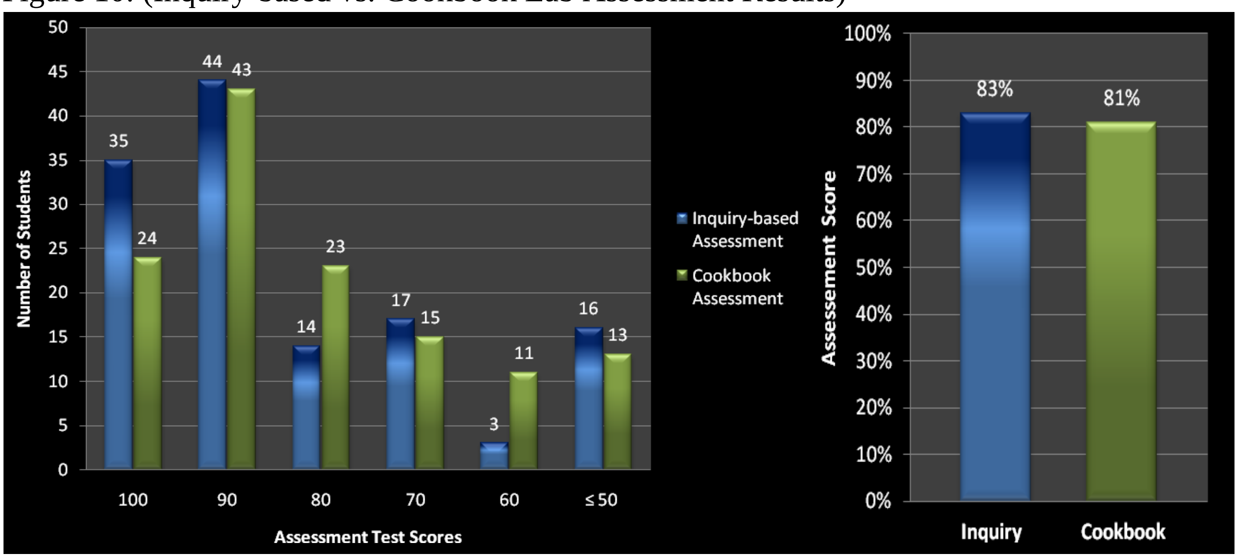



*Cookbook vs. Inquiry-based Lab Assessment Results*

The district standardized test results did not offer conclusive data on measuring differences in student understanding between the two lab approaches, nor did they control for differences in the two teachers and their differing teaching styles. For these reasons, a cookbook versus inquiry-base lab assessment was given to the students to give more validity to and confidence to any differences seen in student understanding. These two assessments were administered 14 weeks after the completion of the chemistry treatment labs and seven weeks after the density and buoyancy lab treatments.

The mean score for the inquiry-base assessment was higher, but not significantly different ($p=.2$) from that of the cookbook lab assessment. The mean score for the inquiry-based lab assessment was 83% compared to the cookbook lab assessment with 81%. The one difference was in the score distribution. Of the 129 students that took the test, 79 students (61%) on the inquiry and 67 students (52%) on the cookbook assessment, had a score of 90% or better. The number of students that scored 50% or lower was similar for both assessments. Scoring break down for the two assessments can be seen in Figure 10.

Figure 10: (Inquiry-based vs. Cookbook Lab Assessment Results)




*(n=129*   *11 of the 140 students did not take the assessments due to absence)*

The results suggest that students remembered much of what the treatment labs contained. This might because they were all hands-on which allowed them to understand and remember the material.  It suggests that the two approaches are comparable for getting students to understand

and retain the information they learned. This supports studies done by Tretter (2003) and Cacciatore & Sevian (2009) that showed inquiry-based labs did not result in a significant difference in student performance on standardized tests.

The way students performed on these two tests was similar to how many of them historically have scored on science tests. There were a small number of students that scored well on both tests (80% or above), but have historically scored low (below 70%) on other assessments during the year. There were 15 students total that showed a significant score improvement over their historic averages. Of these 15 students, eight had a higher score on the inquiry-based assessment compared to the cookbook assessment.

### *Impact on Teacher*

When looking at implementation of new teaching approaches, it is important not to look at just the benefit for the students, but also the benefit for the classroom teacher. Inquiry-based lab activities can have a positive effect on students and teachers as well. The first thing observed during the first inquiry-based lab, which was the Sublime lab, was the number of students actually engaged in doing the experimentation. Cookbook style lab activities usually result in two to three students doing the majority of mixing, experimenting, and measuring, while the other students sit there minimally engaged. This is more noticeable in those classes where students tend to have behavior issues or struggle academically. When students are not engaged, more time is spent on classroom management. The cookbook style labs in this study are interesting, but do not allow for all students to be engaged at the same time. The limited resources and space to safely conduct the lab play a part in the larger group size and make it necessary to have cookbook labs instead of a more inquiry-based approach.

The three inquiry labs were remarkably different than the three cookbook labs in terms of student engagement. The *Build a Boat lab* kept the majority of students engaged over the entire week the activity took place. The nice thing about that is that the teacher can move around the room and interact with groups without having to spend time with classroom management issues. Inquiry-based science has a noticeable decrease in the need for disciplining students that are bored. Observations noted in the teacher journal showed that over the one week the *Build a Boat lab* activity was conducted only two students from all five class periods needed to be redirected back to focusing on the activity. This compares to an average of three to four students per class period needing to be refocused on the activity when cookbook labs were used. The *Sublime Lab* and the *Amorphous Blob Lab* were similar in terms of student engagement according to the data collected in the teacher journal. Students were engaged in the experiment for the entire length of the class. The one drawback is that students are sometimes so engaged that they do not write anything into their science journals.

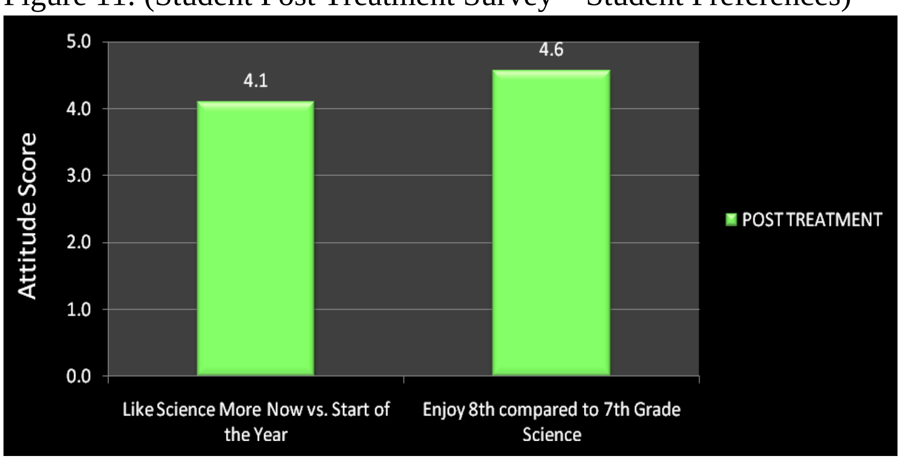
Student observations and interaction with students during the inquiry-based labs showed diversity of thought and resourcefulness that was not observed during the cookbook style labs. Students showed a wide diversity in how they addressed the challenges or conducted experiments. Some students even requested additional lab equipment for the *Sublime Lab* that was not initially supplied by the teacher. Students were looking for interesting and novel ways to use and test the sublimation properties of dry ice. With the *Build a Boat Lab*, students had a variety approaches and ideas which they designed and tested. This is something that would not be possible in the *I Hope it Floats Lab* due to the limitations and more guided direction it afforded the students.

My perception was that an inquiry-based approach was a more positive experience for the teacher compared to the cookbook labs. Observations recorded in the teacher journal showed that during the inquiry-based labs I enjoyed the interaction with the students more, felt they were more engaged, and that the majority of students were actively doing the experiments. Since there was not a rubric or formal data piece to quantify or qualify these observations it should be mentioned that this is a limitation of the study. Conclusions made from these observations are thus limited in their validity.

*Change Over Time*

It is important for me to have my students like science and enjoy learning about the world around them. If students are not enjoying learning about science, they will have little want to further their understanding later. Two questions on the survey focused on student enjoyment while learning science.  Students were also asked if they enjoyed science more now than at the beginning of the year. The other asked them to compare science last year as a 7$^{th}$ grader with science this year as an 8$^{th}$ grader.

Figure 11: (Student Post Treatment Survey – Student Preferences)




*(1=A Lot Less, 2= A Little Less, 3=The Same, 4=A Little More, 5=Much More) (n=140)*

The most significant piece of data might be how student attitudes and enjoyment of science have changed over the course of the year. According to the post-treatment survey, students' like of science, especially compared to 7$^{th}$ grade science, has increased significantly (Figure 11). Whether it is the subject matter, the hands-on approach, inquiry-based labs, or some other factor, it is not clear. The important thing to take from this is that something is being done correctly to get students involved and liking science before they move on to high school.

The results show that an inquiry-based approach can increase student interest and involvement in doing science.  Students seem to prefer inquiry over a cookbook approach, but respond favorably to both. From a teaching standpoint inquiry is the preferred method of lab instruction. The time requirement for planning and administering inquiry-based instruction is greater, but the decreased need for classroom management and the number and quality of student engagement justify the extra resources required.  It appears that both approaches help students to understand the material and allow them to achieve higher scores on standardized tests, although it is not clear which has the greatest impact.

## CONCLUSION

The purpose of this project was to describe the impact inquiry-based lab activities have on middle school science students compared to cookbook style labs. The project shed light on how an inquiry-based lab approach can be used to increase student involvement and interest in doing science.  The project also looked at student understanding of concepts and material when inquiry-based labs are used. Teacher impact and implication was also explored in the study.

*What Was Learned*

Student preference for the inquiry-based labs compared to cookbook styles labs significantly differed. The inquiry-based labs were not only preferred over the cookbook labs (78% vs. 22%), but they were also more interesting and students felt that they were more involved in doing the lab. Students enjoyed the freedom to explore and the privilege to have a say in the experimental process. Letting students have a stake in their learning is one of the things that inquiry-based lab activities foster.

The interviewed students all found cookbook and inquiry-based labs to be interesting. They said that the cookbook labs were interesting and enjoyable. It seems some type of hands-on lab approach, whether inquiry-based or cookbook gets students involved and interested. This suggests that a balanced approach between the lab types can achieve the goal of getting students interested and involved in doing and learning science.

Student preference for science journals compared to answering post-lab questions was an interesting finding in the project. A large majority of students (77%) preferred to keep a journal with observations, data, and reflections, compared to answering the required post-lab questions. Many students say the freedom associated with this type of approach was what they liked most. The quality of these journals did vary greatly. There seems to be a correlation between those students who had higher grades, and put more effort into their journals, compared to those who generally had lower grades in science, who put forth less effort. The one interesting thing is that each student made some effort entering observations, data, or reflections from each of the lab activities.

Student understanding of the concepts and materials was comparable to that offered by a non-inquiry-based approach. The student average for the chemistry standardized test was in the

B average range (82%), almost the same as the non-inquiry-based group (85%). The inquiry-based group had a higher average mean score on the density and buoyancy standardized test (85%) compared to the non-inquiry-based group (81%). On the two lab assessments, which were given many months after the treatment labs had concluded, students scored similarly on the inquiry-based lab assessment (83%) and the cookbook lab assessment (81%) suggesting that they understood and retained the information they learnt from these lab experiences.

It seems that inquiry-based labs do get students more involved and interest in doing science. A hands-on, demonstration supported approach to teaching science is what students at this level feel they best learn from and enjoy. They also seem to want the freedom to decide, but they also feel that they need some direction and guidance.

The inquiry-based approach has allowed me to enjoy teaching the material a little more compared to a strict cookbook lab approach. Some of the cookbook labs were frustrating because there would always be students who were not engaged in the activity and/or became behavior concerns. With inquiry-based labs this frustration has decreased and allowed me to focus on those students that need guidance or help with the lab. The activities have also sparked my interest because of the unique ways students will execute the lab or address the challenges. There has been some pretty impressive work done by the students in this study. You just do not get this type of variety with the cookbook style labs.

*Value and Implications*

The project revealed that students at this level enjoy an inquiry-based approach. If students are engaged and interested in doing science at this level, maybe it will carry over to high school and beyond. The inquiry-based lab approach shows students that science can be interesting and fun. The gathering of data, making mistakes, and testing out ideas are all part of the learning process. Students are allowed to take risks without the fear of answering the questions wrong or not getting the right answer. Self confidence and motivation to meet challenges are of tremendous value to the students. These lab activities allow them to do both.

After seeing how involved and interested students are with the inquiry-based labs, I am more inclined to start transitioning cookbook labs to be more inquiry-based. Not all labs can be made to be completely inquiry-based. Concerns for safety and the need for students to have enough prior knowledge and understanding of concepts make the use of some cookbook style labs an important component of a balance science lab experience. Research done by Kirschner, Sweller, and Clark (2006) suggest that students need some guidance, which cookbook style labs provide, and do not benefit from a minimalist lab approach. The goal would be to bring different degrees or levels to each of the lab activities done in the class. This could mean having students develop their own data tables, procedures, or adding an element of choice in how they showcase their data and findings.

I have only given my students a small taste of inquiry. Over the next few years that taste will increase as I learn more about how to develop quality inquiry activities and work with others at my school in developing worthwhile and meaningful lessons. After I have had more experience using and transferring material to inquiry-based activities, I would like to collaborate with other curricular areas to have them develop activities that have an inquiry touch. If students are exposed to this type of method in all of their classes it will help them to perform inquiry activities at a higher level.

One implication near term is to revisiting and improving the treatment labs I used in this project. The SK8 Motion Lab has already been redone for use next year. I learned a lot from watching students do the labs and from what they have written in their science notebooks. I look forward to taking the rest of the labs and adjusting them to help students enjoy and meaningfully experience inquiry.

*Questions that the Project Raises*

The inquiry-based model seems to be a valuable teaching tool, but there are some questions and concerns of its use in the classroom. A list of concerns and questions follow:

- Do students really understand what they are doing and the material they are learning?
- What will be the long term benefit, if any, of being exposed to inquiry-based science as students attend high school and beyond?
- Will this approach allow them to better understand and do science at the next level?
- Does the increased interest in this science class encourage more students towards a path of study or a profession in a science related field?
- How do you develop cookbook style labs into a more inquiry-based approach?
- How do you get other teachers to see the worth of this approach and start implementing inquiry-based activities?
- How do you get students doing inquiry earlier so that they can develop the science skills that inquiry requires?
- How do you encourage those students that do not write much in the science journals to write more?
- How do you correct students when they make incorrect assumptions or conclusions based on what happens in the lab activities?

The goal of the project was to increase student interest and involvement in doing science. In four years it would be interesting to see how this group of students did at the next level and what they plan to study at the university. Educators hear from students from time to time, but most never know if what they did in their classroom had any long-lasting, positive effect on their students.

I would also like to investigate authentic assessments that would be representative of an inquiry-based approach. It would be interesting to see if students that are exposed to the inquiry-based approach do well on tests that are inquiry-based.

I would also like to be able to address and answer the questions above. The one thing I have learned going forward is that an inquiry-based approach takes time and effort to implement in the classroom. Not just time creating the materials, but getting students to benefit and learn from the activities they are involved in when doing inquiry. It takes extra time to transfer existing curriculum and lessons into an inquiry-based concept teaching approach.

Much has been learned in terms of how to look at what and how students are being taught and making that experience as involved and interesting as possible. A project like this requires educators to take a look at what we have done and decide if it is what is best for kids. Teachers should always be analyzing what we do and understanding why it benefits kids. There needs to be some point in each student's educational journey that allows and encourages them to explore and answer questions that pop into their heads as they move along. This is what is best for kids, but not always easy to produce in the classroom. It is the job of science teachers to encourage students to start asking the questions, solving the problems, and doing the science that gets them involved in learning and discovery. Inquiry is a tool that allows students to start this journey.

## Works Cited

California State Board of Education. (2003). *Science content standards for California public schools. Kindergarten through grade twelve.* Retrieved May 10, 2009, from California Department of Education
Web site: http://www.cde.ca.gov/be/st/ss/documents/sciencestnd.pdf

Cacciatore, K. & Sevian, H. (2009). Incrementally approaching an inquiry lab curriculum: can changing a single laboratory experiment improve student performance in general chemistry? *Journal of Chemical Education, 86(4),* 498-505.

Gerber, BL, Cavallo, A, & Marek, EA. (2001). Relationships among informal learning environments, teaching procedures and scientific reasoning ability. *International journal of science education*, 23(5), 535-.

Humphrey, G. (1995). Inquiry based science: what does it look like?, *Connect*, 8 (58), 13-.

Kirschner, PA, Sweller, J, & Clark, RE. (2006). Why minimal guidance during instruction does not work: An analysis of the failure of constructivist, discovery, problem-based, experiential, and inquiry-based teaching. *Educational Psychologist*, 41(2), 75-.

Karabulut, U. S. (2002). Curricular elements of problem-based learning that cause developments of self-directed learning behaviors among students and its implications on elementary education. Unpublished doctoral dissertation, The University of Tennessee, Knoxville.

Llewellyn, D. (2002). Inquire within: Implementing inquiry-based science standards. Thousand Oaks, CA: Corwin Press.

Lord, T, & Orkwiszewski, T. (2006). Moving from didactic to inquiry-based instruction in a science laboratory. *The American Biology Teacher*, 68(6), 342-.

Marbach-Ad, G. & Sokolove, P.G. (2000). Can undergraduate biology students learn to ask higher level questions? *Journal of Research in Science Teaching*, 37, 854-870.

Mayer, R. (2004). Should there be a three-strikes rule against pure discovery learning? The case for guided methods of instruction. *American Psychologist*, 59, 14–19.

Peters, E. (2005). Reforming cookbook labs. *Science Scope*, 19, 16-21.

Smolleck, L, & Yoder, E. (2006). Further development and validation of the teaching science as inquiry (TSI) instrument. *School Science and Mathematics*, 108(7), 291-297.

Sungur, S, & Tekkaya, C. (2006). Effects of problem-based learning and traditional instruction on self-regulated learning. *The Journal of educational research*, 99(5), 307-.

Tretter, TR, & Jones, M. (2003). Relationships between inquiry-based teaching and physical science standardized test scores. *School science and mathematics*, 103(7), 345-.

Volkmann, M, & Abell, S. (2003). Rethinking laboratories, *The Science Teacher*, 38-41.

# APPENDICES

APPENDIX A

## <u>Your Attitude Towards Science and Doing Science (Pre-Treatment)</u>

**<u>Directions</u>:** Please answering the following questions honestly and as truthfully as you can. **<u>Please circle</u>** the response (**the number**) that you most agree with for questions 1-14. For numbers 15-17 give one or more suggestions for each question. *Thank you.*

1. On the scale below, please rate how much you like science compared to your other classes.

| 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|
| Hate It | Near the Bottom | In the Middle | Near the Top | My Favorite Class |

2. Overall, how interesting do you find science?

| 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|
| Very boring | Mostly boring | Somewhat | Very | Extremely |

3. How interesting are the labs in science class?

| 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|
| Not at all | Very little | Somewhat | Very | Extremely |

4. When I was in elementary school we had many lab activities.

| 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|
| None | Very few | Some | Many | Always |

5. My first real science lab activities were in middle school.

| 1 | 3 | 5 |
|---|---|---|
| Disagree | Maybe | Agree |

6. I learn the most about science when I'm engaged in lab activities.

| 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|
| Disagree | Not Really | Sometimes | Agree | Strongly Agree |

7. I think I learn best when I read information from a book or worksheet.

| 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|
| Disagree | Not Really | Sometimes | Agree | Strongly Agree |

8. I think I learn best when I can do "hands-on" type science activities

| 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|
| Disagree | Not Really | Sometimes | Agree | Strongly Agree |

9. I prefer lab activities that tell me exactly what to do compare to ones that allow me to explore possible ways to do the lab.

| 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|
| Disagree | Not Really | Sometimes | Agree | Strongly Agree |

10. I enjoy doing lab activities that allow me choices in how I do the activity.

| 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|
| Disagree | Not Really | Sometimes | Agree | Strongly Agree |

11. I enjoy reading the directions on how to do the activity when doing science lab.

| 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|
| Disagree | Not Really | Sometimes | Agree | Strongly Agree |

12. What is the most interesting part of labs in science class?

| 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|
| The Introduction | The directions | Doing the Experiment | Seeing the results | Answering the lab questions |

13. What is the most boring part of labs in science class?

| 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|
| The Introduction | The directions | Doing the Experiment | Seeing the results | Answering the lab questions |

14. Do you prefer activities that tell you exactly what to do or ones that allow you to choose the best way to find a solution?

| 1 | 2 |
|---|---|
| Labs that tell me exactly what to do | Labs that allow me to choose |

15. How are labs most helpful to you in increasing your understanding of science?

16. How are labs **not** helpful to you in increasing your understanding of science?

17. Please give one or more ways labs could be made to be more interesting in science.

## Attitudes Towards Learning and Doing Science (Post-Treatment)

**Directions:** Please answering the following questions honestly and as truthfully as you can. **Please circle** the response (**the number**) that you most agree with for each question. *Thank you.*

1. On the scale below, please rate how much you like science compared to your other classes.

| 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|
| Hate It | Near the Bottom | In the Middle | Near the Top | My Favorite Class |

2. Overall, how interesting do you find science?

| 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|
| Not at all | Very little | Somewhat | Very | Extremely |

3. How interesting are the labs in science class?

| 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|
| Not at all | Very little | Somewhat | Very | Extremely |

4. Rate how much you like science today compared to the start of the year?

| 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|
| A Lot Less | A Little Less | The Same | A Little More | Much More |

5. I enjoy the science labs **this year** ($8^{th}$ grade) compared to the science labs **last year** ($7^{th}$).

| 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|
| A Lot Less | A Little Less | The Same | A Little More | Much More |

6. I learn the most about science when I'm engaged in lab activities.

| 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|
| Disagree | Not Really | Sometimes | Agree | Strongly Agree |

7. I think I learn best when I read information from a book or worksheet.

| 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|
| Disagree | Not Really | Sometimes | Agree | Strongly Agree |

8. I think I learn best when I can do "hands-on" type science activities

| 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|
| Disagree | Not Really | Sometimes | Agree | Strongly Agree |

9. I prefer lab activities that tell me exactly what to do compared to ones that allow me to explore possible ways to do the lab.

| 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|
| Disagree | Not Really | Sometimes | Agree | Strongly Agree |

10. I enjoy doing lab activities that allow me choices in how I do the activity.

| 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|
| Disagree | Not Really | Sometimes | Agree | Strongly Agree |

11. When doing a lab I prefer to be given a goal or a challenge to prove (and deciding how to prove it) compared to being told what I must measure or find out (and being told exactly how to do the lab step-by-step).

| 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|
| Disagree | Not Really | Sometimes | Agree | Strongly Agree |

12. When doing a lab I prefer to be told what I must measure or find out (and being told exactly how to do the lab step-by-step) compared to being given a challenge or goal to prove (and deciding how to prove it).

| 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|
| Disagree | Not Really | Sometimes | Agree | Strongly Agree |

13. Do you prefer activities that tell you exactly what to do or ones that allow you to choose the best way to find a solution?

| 1 | 2 |
|---|---|
| Labs that tell me exactly what to do | Labs that allow me to choose |

14. Thinking back to the **<u>Skate Motion Lab</u>**, did you enjoy learning about physics this way?

YES NO

15. Did you feel you were involved in doing the experimenting in the lab?

| 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|
| Not at all | A Little | Somewhat | A Lot | Completely |

16. Did you prefer the **<u>Hot Wheels Lab</u>** or the **<u>Skate Motion Lab</u>**?

| 1 | 2 |
|---|---|
| Hot Wheels Lab | Skate Motion Lab |

17. Thinking back to the **<u>Sublime Lab</u>** (Dry Ice), did you enjoy learning about matter this way?

YES NO

18. Did you prefer the **Sublime Lab** or the **Exo/Endothermic Lab** (the one that got hot/cold)?

| 1 | 2 |
|---|---|
| Sublime Lab | Exo/Endothermic Lab |

19. Did you feel you were more involved in doing the experimenting in which lab?

| 1 | 2 |
|---|---|
| Sublime Lab | Exo/Endothermic Lab |

20. Thinking back to the **Amorphous Blob Lab** (cornstarch & water), did you enjoy learning about matter this way?

YES NO

21. Did you prefer the **Amorphous Blob Lab** or the **Making Silver and Falling Snow Lab**?

| 1 | 2 |
|---|---|
| Amorphous Lab | Making Silver & Snow Lab |

22. Thinking back to the **Build a Boat** (Styrofoam boats), did you enjoy learning about buoyancy & S.A. this way?

YES NO

23. Did you prefer the **Build a Boat Lab** or the **I Hope It Floats Lab?**

| 1 | 2 |
|---|---|
| Build a Boat | I Hope It Floats |

24. Did you feel you were more involved in doing the experimenting in which lab?

| 1 | 2 |
|---|---|
| Build a Boat | I Hope It Floats |

25. Why do you enjoy the labs where you are given a challenge and then decide how to test for or solve the problem?

<u>APPENDIX B</u>

Dear Parents and Students,

I am currently working on my final thesis project for my masters in science education at Montana State. One of the requirements for the degree is to develop a project that allows me to explore ways to improve my teaching practices. Over the last year I have incorporated a new lab activity approach that allows students a more inquiry-based experience. It seems to me that this new approach, which allows students more choices in the experimental processes of the labs, has resulted in more interaction and interest in learning science in my class. To confirm that this is true I need to conduct student interviews in addition to the observations I have already made.

With your permission, I would like to ask your son or daughter questions on how they enjoyed and what they learned from the new lab approach. This will be done during class, taking no more than five to ten minutes. The student responses will be used to confirm whether or not students are benefiting from the labs. Names and other student personal information **will not** be included in my project or paper.

Thank you in advance for your support. A copy of my final project will be available from my website for download later this summer. Please visit http://www.sierravistams.org/mathot/ to download the document.

Sincerely,

Mr. Jean Philip Mathot

Science Teacher - Sierra Vista Middle School

_____ I give permission for my child to be interviewed for Mr. Mathot's research project.

______I do not give permission for my child to be interviewed for Mr. Mathot's research project.

Parent Signature:_____________________________________________ Date: ____________

APPENDIX C

**INTERVIEW QUESTIONS**

1. What was your favorite lab we did this year? Why?
2. Which ones were most interesting?
3. Which labs this year did you find allowed you to be most involved? How?
4. Which labs did you feel you were least involved in doing the experiment? Why?
5. Do you tend to do the work during labs or let some else do the experiments?
6. Do you prefer lab activities that have post-lab questions to answers or lab activities that have you do a science journal for writing your data, observations and what you learned?
7. What physics or chemistry did you learn from the lab activities we did?
8. How do you feel you best learn science (demos, labs, hands-on, notes, vocab, the textbook, lecture)?
9. Which type of lab approach do you prefer: cookbook (step-by step directions) or inquiry-based (student decides how to conduct the activity)?
10. Do you enjoy science better this year or science last year? Is it the concepts (Physics and Chemistry vs. Biology and Health) or the labs activities?
11. What could be done to make this class better?

APPENDIX D

## California State Science Standards – $8^{th}$ Grade

| Lab Activity | Standard Covered* |
|---|---|
| SK8 Motion Lab | **Motion: The velocity of an object is the rate of change of its position.**<br>1b. average speed is the total distance traveled divided by the total time elapsed. The speed of an object along the path traveled can vary.<br>1c. how to solve problems involving distance, time, and average speed. |
| Hot Wheels Motion Lab | **Motion: The velocity of an object is the rate of change of its position.**<br>1b. average speed is the total distance traveled divided by the total time elapsed. The speed of an object along the path traveled can vary.<br>1c. how to solve problems involving distance, time, and average speed.<br>1e. changes in velocity can be changes in speed, direction, or both. |
| Sublime Lab | **Structure of Matter: Elements have distinct properties and atomic structure. All matter is comprised of one or more of over 100 elements.**<br>3d. the states (solid, liquid, gas) of matter depend on molecular motion.<br>3e. in solids the atoms are closely locked in position and can only vibrate, in liquids the atoms and molecules are more loosely connected and can collide with and move past one another, while in gases the atoms or molecules are free to move independently, colliding frequently.<br>**Reactions: Chemical reactions are processes in which atoms are rearranged into different combinations of molecules.**<br>5d. physical processes include freezing and boiling, in which a material changes form with no chemical reaction. |
| Amorphous Blob Lab | **Structure of Matter: Elements have distinct properties and atomic structure. All matter is comprised of one or more of over 100 elements.**<br>3c. atoms and molecules form solids by building up repeating patterns such as the crystal structure of NaCl or long chain polymers.<br>3d. the states (solid, liquid, gas) of matter depend on molecular motion.<br>3e. in solids the atoms are closely locked in position and can only vibrate, in liquids the atoms and molecules are more loosely connected and can collide with and move past one another, while in gases the atoms or molecules are free to move independently, colliding frequently. |
| Exothermic/ Endothermic Lab | **Reactions: Chemical reactions are processes in which atoms are rearranged into different combinations of molecules.**<br>5a. reactant atoms and molecules interact to form products with different chemical properties.<br>5c. chemical reactions usually liberate heat or absorb heat. |
| Making Silver and Falling Snow | **Reactions: Chemical reactions are processes in which atoms are rearranged into different combinations of molecules.**<br>5a. reactant atoms and molecules interact to form products with different chemical properties. |
| I Hope it Floats Lab | **Density and Buoyancy: All objects experience a buoyant force when immersed in a fluid**<br>a. density is mass per unit volume.<br>c. the buoyant force on an object in a fluid is an upward force equal to the weight of the fluid it has displaced.<br>d. how to predict whether an object will float or sink. |
| Build a Boat | **Density and Buoyancy: All objects experience a buoyant force when immersed in a fluid**<br>a. density is mass per unit volume.<br>c. the buoyant force on an object in a fluid is an upward force equal to the weight of the fluid it has displaced.<br>d. how to predict whether an object will float or sink. |

**Source:California Department of Education (2003) - http://www.cde.ca.gov/be/st/ss/documents/sciencestnd.pdf*

APPENDIX E

# SK8 MOTION LAB

With a **skateboard, timing device** and **measuring device** you will plan with your group a way to address the following challenges and mysteries of the science behind riding skateboards. Use your notes on the **Scientific Method, Science Vocab #1, Physics Equations #1** and your **creativity** to **safely** address the following aspects of motion and physics.

The **challenges** are listed below. You are to prove that each can be done and performed using a skateboard. **All** ideas, experiments, data, notes, conclusion, drawings, etc should be **written down in your notebook**.

**The Challenge**

1. Find out **how fast** you are going for **each person** in your group.
2. Find a way to get everyone in your group to have the **same velocity**.

**You need to address the following in your notebook:**

1. Include a picture and/or sketch of your experiment. **Make sure it is SAFE!**
2. Explain how you will do your experiment or how you will be collecting data. Your group should conduct a minimum of **3 trials** per each rider and take the average of those 3.
3. Include a place to record the data (data table): Quantitatively
4. Include notes, observations or things you learned while doing the experiment Qualitative (characteristic).
5. Write down and discuss **what has been discovered or found out** by doing this experiment. Look at your data and discuss what you learned and if you were able to all have the same speed.

# Hot Wheels Motion Lab

**PURPOSE:**

To measure and calculate the distance a car travels divided by the time it takes it to go that distance (Average Speed).

**MATERIALS**

1 Race Track

2 Hot Wheels Cars

2 Stopwatches

1 Meter Stick

| HELPFUL EQUATIONS TO WRITE DOWN IN YOUR SCIENCE NOTEBOOK |
|---|
| • Speed=<br>• Avg. Speed = |

**PROCEDURES:**

<u>Part 1: Average Speed, Velocity, and Acceleration</u>

1. **<u>Do not</u> write on this lab**. Please write everything in your science notebook.
2. **<u>Write down</u>** (right now) the formulas for **SPEED, AVERAGE SPEED,** and **ACCELERATION**.
3. Use your **<u>Physics #1 Equation Notes</u>** we took in class to help with the calculations. When doing calculations for this lab please **<u>SHOW ALL WORK AND FORMULAS</u>** (I will write this again next to the calculations part to help remind you what to do).
4. Get the equipment listed above in the quantities listed above (should be at your table already).
5. **<u>Make a data table</u>** to record and calculate your measurements (Table 1).

Table I: Distance vs. Time

| | Trial #1 (**half way – 95 cm**) | | Trial #2 (**entire length of track**) | |
|---|---|---|---|---|
| | *Distance (cm)* | *Time (sec.)* | *Distance (cm)* | *Time (sec.)* |
| Run #1 | *95* | | *190* | |
| Run #2 | *95* | | *190* | |
| Run #3 | *95* | | *190* | |
| **Average***: | 95 cm | _____sec. | 190 cm | _____sec. |
| * Add all 3 run times together and divide by 3 to get the average time for that distance | | | | |

6. Select a car and either lane 1 or 2 for all of your data collection. The **two lanes are not the same** in how fast they launch the car. This means that you need to **use the same lane for ALL** of the runs.
7. The first three runs are for getting the time it takes the car to go 95 cm. You will write the time for each run in your data table.
8. Place the cars in the starting area. Push car in so the spring loads.
9. Make sure the **yellow** finish line flags are **DOWN** before you launch your cars.
10. Use the meter stick to measure 95 cm down the track (starting from the front of the car).
11. **Please** make sure not to launch the cars off of the table. ***Thank you from the garage.***
12. **One person** should launch the car and (start/stop) the stop watch. You can **take turns** and have a different person do this for each run.
13. **Launch** the car and **record the time** for each of the three runs at **95 cm**.
14. You will do an addition three runs at **190 cm** (entire length of track). Record in data table.

15. After you do three runs **take the average time for the three runs** (use that as the **Average** and write in data table). This will be the time you use in your calculations (on back of this piece of paper).
16. Once you have your data table completed with the distances and times, move on to doing the calculations, making the graph and answer the post-lab questions.

**CALCULATIONS: (Show all work and formulas. Setup each problem like we did in class with the grocery list approach for all the variables)**

1. Calculate the **average speed** for your car from 0 cm to 95 cm.
2. Calculate the **average speed** for your car from 0 cm to 190 cm.
3. Calculate the **average speed** for your car from 95 cm to 190 cm.
4. Calculate the **acceleration** for the car for the **First** 95 cm of the track (USE your answer from calculation #1 above for $V_2$ and $V_1 = 0$).
5. **Plot a graph** of distance vs. time for your car. Use your book for help (Chapter 1& 9) and the **graph on the overhead**. (Distance will be on the y-axis and time will be on the x-axis). If you are plotting distance vs. time, what are you really plotting? (Hint: shhh, don't talk).

**POST LAB QUESTIONS:**

1. List three things that are causing the car to accelerate? (**Hint**: acceleration is **change in velocity**)
2. Where was the acceleration of the car the greatest? (**Think** about what is causing it to accelerate)
3. Is the speed of the car constant or does it change as it goes down the track? Explain how you know (**Hint**: look at your graph).

4. Are the velocity and the speed of the car the same in this experiment? Explain your answer in a complete sentence.
5. In the 1996 Olympics, gold medal winner Michael Johnson had a **faster average speed** in his **400-meter** race compared to his **100-meter race**. Why?
6. A man once told me that if someone is going to hit you and you cannot get out of the way of the punch, you should lean in closer to the person as they swing at you. Explain how acceleration relates to this and if the guy gave me good information.
7. What two things could you do to increase the momentum of the car?

<u>APPENDIX F</u>

## <u>**Sublime Lab**</u>

### <u>**INTRODUCTION:**</u>

Dry Ice is composed of the elements Carbon and Oxygen. It is the <u>**solid phase**</u> of the <u>**gas**</u> carbon dioxide ($CO_2$). It is a unique compound because it <u>**sublimes**</u> under normal atmospheric pressure and conditions. This means it does not change to liquid state when it goes from solid to gas. Today, you will have the chance to experiment with this matter.

<u>**Remember,**</u> lab safety for yourself and other is the most important concern in the classroom. This matter is generally safe as long as you do not misuse or mishandle it (*meaning use your goggles at all time, wear gloves and do not do anything unsafe to you or others*).

### <u>**MATERIALS:**</u>

- Balance, flask, plastic cups, balloon, film canister, thermometer, tongs and <u>**GOGGLES**</u>.

### <u>**CHEMICALS:**</u>

- **Dry Ice -** Carbon Dioxide ($CO_2$)

### <u>**Things you can do:**</u>

- Get water, use the balance, inflate the balloons, put into a container (be careful), use the thermometer, or anything else that is safe and will allow you to experiment with the matter.

### <u>**What You Need to Do:**</u>

- <u>**First, put on your gloves and goggles**</u>
- Next, observe and <u>**list 3 unique characterizes**</u> about a piece of dry ice. <u>**Sketch a picture into your notebook**</u>

- Next, use any of the items at your table to experiment with a piece of dry ice. You will **do 3 different experiments or make 3 measurements**. Make sure you **sketch and describe** the experiment you are doing. **Record any data** you collect (numbers or observations). **Explain** what is going on and/or **what you have learned and discovered**.
- **Clean up** after you have done at least 3 experiments.

## **Amorphous Blob Lab**

### **INTRODUCTION:**

Matter can exist in different states or phases. Most matter we interact with in our daily lives is in the solid, liquid and/or gas phases. When matter changes from one phase to another it represents a physical, **not** chemical change. The change from one state of matter to another is a result of the movement of the atoms that make up the matter. When a solid (like ice) melts and becomes water, the molecules that make up water (2 Hydrogen and 1 Oxygen) start moving faster (gain energy in the form of heat) and move further apart from one another. If even more energy (heat) is absorbed by the water molecules it can turn into water vapor (a gas).
Each of the three states (solid, liquid and gas) have unique characteristics and traits. Solids (atoms tightly packed) have a definite shape and do not take the shape of the container they are place in. Liquids (atoms further apart) take the shape of the container they are placed in and can be poured. Gases (atoms very far apart) fill up container they are placed in and can also be poured.

The tricky part of all of this is that some matter does not fit nicely into the definition of a solid, liquid or gas. Some matter can have characteristics of more than one state or phase of matter. You are going to see such matter today in this lab. **Remember,** lab safety for yourself and other is the most important concern in the classroom. This matter is generally safe as long as you do not misuse or mishandle it (*use your goggles at all time*). *Enjoy*

### **Definition:**

**Amorphous Solid** – A solid with no definite shape that acts both like a solid and liquid.

**MATERIALS:**

- Balance, cups, spoon, paper plate and **GOGGLES**.

**CHEMICALS:**

Corn starch $(C_6H_{10}O_5)_n$, Water ($H_2O$), Table salt ($NaCl$),

**The Challenge - What You Need to Do:**

- **FIRST** - Observe and **list 3 unique characterizes** about the corn starch and water mixture. **Sketch a picture into your notebook**
- **SECOND** - Figure out **what state of matter** the corn starch and water mixture is. Write three compelling (good evidence for) reasons for your beliefs. Make sure you include your observations and any experiments you did to back up your reasoning.
- **THIRD** – give at least three reasons why salt ($NaCl$) is a solid and not a liquid. Make sure you look at the definition of a solid and liquid before addressing this challenge
- **LAST** - **Clean up** after you have finished the three challenges.

# <u>**Build a Boat**</u>

<u>INTRODUCTION:</u>

There are a couple of factors that determine if an object, such as a boat, will float or sink when placed in water. The **density** of the object (your boat) relative to the density of the water ($1 g/cm^3$) is important to the object floating or sinking. If the density is larger than that of water it is more likely that the object will sink. Another factor that has a significant impact on whether or not it will sink when placed in water is the **Surface area** of the boat. In general, the larger the surface area the more able the object is to stay afloat in water (even if the density is greater than that of water). The increased surface area allows for a larger amount of water to support the mass of the object over a given area. In other words, the more area the less pressure at any given point. <u>**Example**</u>: it is easier to stay afloat in a pool if you lay on your back compared to having your feet straight down. The increased surface area (your back) allows more water to support your weight versus to the water underneath your feet.

Any object placed in water will experience a <u>**buoyant force**</u> upwards (opposes gravity). This results in a decrease in weight of the object because an outside force (buoyancy) is acting opposite gravity (downwards) to reduce the net force acting on the object. This results in a decrease in the weight (which is a force) of the object when placed in water. Interestingly, Archimedes discovered that the mass of water that is **displaced** (equal to the volume of the object placed in the water) equals the buoyant force experienced by the object. The more displacement your boat has, the more buoyant force it will have and the more weight it should be able to support.

Your goal is to make a boat that will float as much weight as possible. The only catch is that it cannot have a mass greater than **40 grams** and must have a **length of 50 cm or less** and a **width of 36 cm or less**.

MATERIALS:

- Balance, Styrofoam, plates, wood, glue or anything else you would like to use (be safe).

THE CHALLENGE - What You Need to Do:

- **FIRST – List** the major factors (**at least two**) that affect how well a boat floats. Explain how they affect the boat you will design.
- **SECOND** - Sketch **at least one** design that you think might work or that you plan to build. You can change, update, or add additional designs as you do this lab activity.
- **THIRD** - Build a boat out of any of the materials available in class. The requirements are that it can have a **maximum mass of 40 grams, a maximum length of 50 cm and a maximum width of 36 cm**. Test and retest your boat as you build it. Record **observations, data, and insight** into how well your design does along the way.
- **FOURTH** - Test and redesign as often as needed (until due date). Make sure you put all these **findings, design notes, and results** into your science notebook.
- **LAST** - **Clean up** after you have finished the four challenges above.

APPENDIX G

# <u>Exothermic /Endothermic Chemistry Lab</u>

<u>INTRODUCTION:</u>

The following two experiments will allow you, the chemist to explore the wonderful world of chemical reactions. Endothermic, exothermic, decomposition reactions, and conservation of mass (matter) are the main concepts demonstrated by the following experiments (*see* Chem. Notes #2 for more info). In studying the reactions that occur, you will start to get a feel for reaction types and the types of products the reactants form. <u>Remember</u>, lab safety for yourself and other is the most important concern in the classroom. These reactions and chemicals are generally safe as long as you do not misuse or mishandle them.

<u>MATERIALS:</u>

- Balance, 125 ml flask, plastic cup, funnel, thermometer, and <u>GOGGLES</u>.

<u>CHEMICALS:</u>

- PART I- Potassium Chloride (KCl) and water. PART II- Calcium Chloride ($CaCl_2$) and water.

<u>PART I</u> Rxn: $KCl + H_2O \rightarrow K^+ + Cl^- + H_2O$

1. <u>The following is what you need</u> to write down in your science notebook: data table, graph of data for each reaction (temperature vs. time) & all post-lab questions answers.
2. <u>Copy</u> down Data Table I into your science notebook (page 2 of this lab).
3. PUT ON YOUR GOGGLES RIGHT NOW! <u>YES, RIGHT NOW</u>. Continue as normal once this has been completed.
4. Put <u>50 ml of $H_2O$</u> in the <u>125 ml flask</u>.

5. Put a thermometer in the flask and record the temperature ($^oC$) after <u>1 minute</u>.
6. Write down the <u>starting</u> temperature of the water in your data table.
7. Have ONE person from your group bring the plastic cup to the chemical table (not the beaker) to get the <u>Potassium Chloride</u>. Make sure the balance is zeroed.
8. After zeroing, place the plastic cup on the balance to get its mass (approximately 3g). Move the weights so it is now <u>15 grams MORE</u> than the mass of the plastic cup (*18g total*).
9. Measure out <u>15 g of Potassium Chloride</u> (KCl). As you add the chemical the balance will move to zero and be balanced (this is when you know you have 15 grams of the chemical). Bring the chemical in the plastic cup back to your table.
10. Use the funnel to pour the 15 g of Potassium Chloride into the 50 ml of water (at your table & not at the chemical table). <u>Try not to let the funnel touch the water</u>. You can also turn the funnel upside down or tap it if the chemical gets stuck in the funnel.
11. Mix the chemical <u>quickly for 5 seconds</u> by swirling the flask around carefully.
12. Observe the temperature change over the <u>first minute</u>. Record the temperature <u>every 5 seconds</u> and record into your data table.
13. When finished, pour the solution in the container labeled <u>KCl solution and $CaCl_2$ solution</u>.
14. Rinse the flask out in the sink to get rid of any remaining chemical. You will use the same flask with the second chemical in PART II. <u>DO NOT GET THE PLASTIC CUP OR FUNNEL WET.</u> It is okay if there is chemical still in the plastic cup for Part II.

1. Answer all the post lab questions and create a graph for each reaction <u>AFTER</u> you finish Part II.

---

Part II Rxn: $CaCl_2 + H_2O \rightarrow Ca^+ + Cl_2^- + H_2O$

2. Repeat steps 4 through 13 from above for the $CaCl_2$ and $H_2O$ reaction. The steps are the same except you will be using the second chemical ($CaCl_2$).
3. When done, clean up your table and pour out the $CaCl_2$ solution. Wash your hands before taking off your goggles. Put goggles back into the goggle cabinet. Thank you.

Graph:

1. Create a graph for each of the two chemical reactions (2 graphs total) showing the data you collected (temperature vs. time). See example graph for more information.

Post Lab Questions:

Part I: $KCl + H_2O \rightarrow K^+ + Cl^- + H_2O$

1. Was this an endothermic or exothermic reaction? How do you know (what data do you have that supports you answer)?
2. Was there any physical change in the solution?
3. Was it a decomposition or synthesis reaction (See Rxn. Equation above)? How do you know?
4. What was the temperature change (show your work)?
5. Where in the real world could this chemical reaction be useful? Why would it be useful in the situation you suggested?
6. If you added twice the amount of Potassium Chloride, what do you think would have happened to the temperature? Why?

Part II: $CaCl_2 + H_2O \rightarrow Ca^+ + Cl_2^- + H_2O$

1. Was this an endothermic or exothermic reaction? How do you know (what data do you have that supports you answer)?
2. Did it look like anything was reacting? How did you know there was a reaction then?
3. Was there any physical change in the solution?
4. Was this reaction a decomposition or synthesis reaction?
5. Where in the real world could this chemical reaction be useful? Why would it be useful?
6. I did this experiment last night, but the temperature on my thermometer reached up to 65 $^0C$. Why did my experiment reach a higher temperature then yours (think Chem. #2 notes)?

Data Table 1: Reaction Temperatures (Temperature of $H_2O$ at Start, during & Finish of Rxn)

| Time | Temperature | |
|---|---|---|
| | Part 1 ($KCl + H_20$) | Part 2 ($CaCl_2 + H_20$) |
| 0 sec (the starting temp of water) | | |
| 5 sec | | |
| 10 sec | | |
| 15 sec | | |
| 20 sec | | |
| 25 sec | | |
| 30 sec | | |
| 35 sec | | |
| 40 sec | | |
| 45 sec | | |
| 50 sec | | |
| 55 sec | | |
| 60 sec | | |
| Max Change in Temperature $^oC$ | | |
| Reaction Type: (Endothermic or Exothermic) | | |

## THE MAKING OF *SILVER* AND *FALLING SNOW*

## PART I:

## *THE MAKING SILVER OUT OF COPPER WIRE*

**PURPOSE:**

- To watch the affect of **solutes** dissolving and precipitating out (which means to leave) of a **solution** as the result of a **chemical reaction**.
- To see if the **concentration** of the **solution** has an affect on how much **solute** is **produced** (precipitates out) during a reaction.

**The Rxn:** $2AgNO_3 + Cu \longrightarrow Cu(NO_3)_2 + 2Ag$

**MATERIALS:**

GOGGLES, 2 test tubes, test tube rack, and graduated cylinder.

**CHEMICALS:**

$AgNO_3$ (Silver Nitrate), $H_2O$, and copper wire.

**PROCEDURES:**

1. **MAKE SURE YOUR GOGGLES ARE ON YOUR FACE**. Ask someone at your table if you are not sure.
2. **TRY NOT TO GET ANY SILVER NITRATE ON YOUR SKIN**. IT WILL TURN IT **BLACK**, BUT DOES NOT CAUSE MUCH HARM OTHER THAN THAT. IF YOU DO GET IT ON YOU, WASH YOU SKIN FOR AT LEAST 30 SECONDS.
3. Get **10 ml of silver nitrate solution** (**$AgNO_3$**) and pour into **first test tube**.
4. For the **second test tube** get **1 ml of silver nitrate** (**$AgNO_3$**) and **9 ml of Distilled Water** (***NOT** tap water*) (for a total of 10 ml). Pour solution into second test tube.

5. Take **two pieces** of copper wire copper wire back to your table.
6. Place **<u>one piece</u>** of wire in **<u>each</u>** test tube and watch what happens. Be patient.
7. Let the reaction proceed for at least **<u>10 minutes without moving the test tubes</u>**.
8. Answer the questions that follow (start Part II before you do this).
9. Clean up after you have answered the questions. Put solution in the collection container labeled $AgNO_3$ (**<u>including the wire</u>**).

**<u>POST LAB QUESTIONS</u>:** (*Use Chem. Notes #3 to help with the questions)

1. What is happening to the copper wire?
2. What color is the solution turning (it will have a slight color at the end of 10 minutes)?
3. What metal is collecting on the copper wire? (Hint: look at Rxn equation above)
4. What metal is being dissolved into the solution?
5. Which concentration (test tube #1 or #2) has the most metal collecting on the copper wire? Why?
6. How could I make the reaction proceed or go faster? **<u>List at least two ways</u>**.
7. Sketch a picture of the experiment and a 1 sentence explanation into your notebook.

## PART II:

## ***<u>MAKING FALLING SNOW</u>***

**PURPOSE:**

- To **add** a **<u>solute</u>** to a **<u>solvent</u>** and determine if the **<u>solute</u>** is **<u>soluble</u>** in the **<u>solution</u>**.
- To determine if you have created an **<u>unsaturated</u>** or **<u>saturated</u>** **solution.**

**MATERIALS:**

GOGGLES, glass bottle, and black top

**CHEMICALS:**

Boric Acid & $H_2O$ (Tap Water)

**PROCEDURES:**

1. **PUT YOUR GOGGLES ON AND KEEP THEM ON UNTIL YOUR TABLE IS DONE AND YOU HAVE FINISHED CLEANING UP YOUR TABLE AND WASHED YOUR HANDS.**
2. Get boric acid from Mr. Mathot at the chemical table.
3. **<u>NOTICE that the crystals completely cover the bottom of the container</u>**.
4. Fill glass container almost to the top with water. **BE CAREFUL NOT TO OVER FILL AND GET THE ACID SOLUTION ON YOUR HANDS. WASH HANDS THOROUGHLY WITH WATER FOR <u>AT LEAST 30 SECONDS</u> IF YOU SPILL ACID ON YOUR HANDS.**
5. Tightly screw black top on bottle. **DO NOT OVER TIGHTEN**.
6. Shake the glass container to mix the crystals and water (**15 seconds only**). Be careful that the bottle does not leak.

7. Allow jar to stand still for **one minute,** and then observe solution while turning it upside down and right side up.
8. Answer the questions that follow.

   *** Note – <u>No</u> chemical reaction** occurred in the mixing of boric acid with water.
9. **Cleanup <u>after</u>** you answer the questions. Pour boric acid solution into labeled collection container**, <u>NOT down the sink</u>**. **<u>DO NOT DRINK</u>** (**especially male students**).

**<u>POST LAB QUESTIONS</u>:** (*Use Chem. Notes # 3 & Vocab. to help with the questions)

1. What was the solvent? What was the solute?
2. Did the boric acid mix with the water? Explain.
3. If you added more boric acid, what would you see happen? Why?
4. Turn the bottle upside down. What does it remind you of?
5. What could you have done to make the boric acid dissolve better (list at least 2 ways)?
6. Since not all the boric acid was able to dissolve, we would say the solution is _____________ and that is why some solute was left on the bottom.
7. How would you make this solution unsaturated (list at least 2 ways)?
8. Sketch a picture of the experiment and a 1 sentence explanation into your notebook.

# **I HOPE IT FLOATS** LAB

A Real World Application of the Scientific Method

You have been selected to design and build a metal boat that will float. The boat will be used as a trash barge that will take the trash in your area (where there is no more room to bury it) to another part of the United State so it can be disposed of properly. If you can create a boat that will take away all the trash your city creates (200 grams), all will be well. If your barge design cannot handle the trash you create each day, your city will be buried in a pile of trash and the people of your city will cease to exist *(not good).* Please use the outline for the **SCIENTIFIC METHOD** below to build a trash barge that will save your city. **NOTE:** You must complete up to step 6 before you can get foil and start making your boats. **Please read everything on this page before starting.** Remember, this lab has to do with buoyancy, density, mass, volume and surface area. Thank you.

1. **PURPOSE** (why are you designing and building this trash barge?):
2. **INTRODUCTION** (**Draw/discuss** a few possible designs **AND define** the following):
    a. **Density:(include formula)**
    b. **Mass:(include units)**
    c. **Volume:(include units)**
    d. **Surface area:**
    e. **Buoyancy:**
3. **HYPOTHESIS** (design you think will work best. (flat, deep hull, narrow, round, etc)):
4. **MATERIALS** (aluminum foil **10 X 14 inches (5g)**, metal weights, ruler, & water tank,):

5. **<u>PROCEDURES</u>** (describe how you will make & test your design - 6 steps min.):

6. **<u>DATA</u>** record your results in a data table (like the one below, but in **<u>your notebook</u>**).

   Include the weight supported by each design/dimension you tested.

| **Design** | **Volume**<br>(Length x Width x Height) | **Surface Area**<br>(Length x Width) | **Mass Floated**<br>**(grams)** |
|---|---|---|---|
| 1<br>2<br>3 | | | |

7. **<u>CONCLUSION</u>** (discuss how your design worked. Which dimensions allowed for the greatest weight? Go back through the scientific method (steps 3-7) and try other designs (but only using 1 piece of foil at a time **– DO NOT COMBINE THE PIECES OF FOIL INTO ONE BOAT**).

# APPENDIX H

Science Journal Notebook Grading Rubric

| | 4 | 3 | 2 | 1 |
|---|---|---|---|---|
| Illustration/ Sketch | Neat, well illustrated drawing of experiment or design. | Good drawing which shows the experiment or design. | Has a drawing, but not of good quality, but does show some of the experiment or design. | Has a drawing, but of poor quality and does not clearly show experiment or design. |
| Observations | Multiple, clearly written, and descriptive observations of the experiment. | Multiple written, and descriptive observations of the experiment. | One or two written observations that may not be totally clear. | Observations have little or no description of experiment. |
| Data Collection | Data table and qualitative data clearly listed | Data table with some qualitative data include | Data table or qualitative data included | An attempt at some type of data collected is present, but not enough to draw significant conclusions from the data |
| Conclusion/ Reflection | Student uses observations and data collected to draw logical conclusions and elaborate on what they learned. | Student uses observations and data collected to draw logical conclusions. | Student uses observations or data collected to make at least one comment on what happened. | Student conclusions make little or no sense of do not support observations or data collected |

# APPENDIX I

Sublime, Amorphous Blob, and Build a Boat Lab Assessment

DIRECTIONS: Select the best answer for each question. Just write the capital letter for each multiple-choice question. MAKE SURE YOU READ EACH QUESTION CAREFULLY AND THINK BACK TO THE LABS YOU DID IN CLASS. Good Luck

1. What is it called when a solid goes turns straight into a gas?
   A. evaporation B. condensation C. sublimation D. precipitation E. it's impossible

2. How could you make dry ice turn from a solid to a gas faster?
   A. Put it in hot water
   B. Put it in cold water
   C. Put it in the freezer
   D. It cannot be made to turn to gas faster

3. In what phase (state) is $CO_2$ (carbon dioxide) in its densest form (most dense)?
   A. Plasma B. Solid C. Liquid D. Gas

4. Which of the following best describes an amorphous solid?
   A. a solid that is very sticky
   B. a solid that acts like both a liquid and a solid
   C. a liquid that flows quickly
   D. a liquid with low viscosity

5. Which state of matter has atoms that take the shape of the container they are put into, but cannot be compressed very much?
   A. Liquid B. Solid C. Gas D. Plasma

6. How could you make the cornstarch and water mixture you made act more like a solid?
   A. It cannot be done B. Add more water C. Add more heat D. Add more cornstarch

7 What is the most important thing to increase if you want a boat that floats a lot of weight?
   A. increase its mass B. increase its density C. increase its height D. increase its surface area

8 When you add your boat to the water and add weight it causes the water to be_________?
   A. displaced B. dissolved C. made heavier D. less dense

9 What is the upward force pushing on your boat by the water?
   A. gravity B. density C. centrifugal force D. buoyant force

10 Why did the taller boats not float that much weight?
   A. high center of gravity B. high density C. high surface area D. they were Chabot strong

Exothermic/Endothermic, Making Silver & Falling Snow, and I Hope it Floats Lab Assessment

DIRECTIONS: Select the best answer for each question. Just write the capital letter for each multiple-choice question. MAKE SURE YOU READ EACH QUESTION CAREFULLY AND THINK BACK TO THE LABS YOU DID IN CLASS. Good Luck

1.What is produced during an exothermic reaction?
A. nothing B. cold C. ice crystals D. heat

2. How could you make the reaction with the KCl (potassium Chloride) get colder than it did?
A. Add more KCl to the water
B. Add more tap water to the solution you already made
C. Take out some of the KCl before it all dissolved
D. You cannot make it any colder than it is

3. What type of reaction absorbs heat from the environment?
A. exothermic B. endothermic C. iron rusting D. over reaction

4. What was the metal that precipitated out of the $AgNO_3$ solution and formed on the wire?
A. silver B. copper C. nitrogen D. oxygen E. nitrate

5. How could you make more crystals form on the wire?
A. Make the $AgNO_3$ solution less concentrated
B. Make the $AgNO_3$ solution more concentrated
C. Add more distilled $H_2O$

6. When making the falling snow, not all of the boric acid (the white powder) dissolved. How could you help it to dissolve better?
A. Add more boric acid B. Remove some of the water C. Heat it up and/or shake it

7 Length x Width x Height is equal to what on the aluminum foil boats you made?
A. density B. area C. volume D. mass

8 Why did not the small canoe shaped boats work very well?
A. they did not have a lot of surface area
B. they had too much surface area
C. they had too much volume
D. they were less dense than the other boats

9 Archimedes said that the weight of the water displaced by an object placed in water is equal to the____. A. surface area B. buoyant force C. gravitational force D. friction force

10 Why can metal boats like big aircraft carriers float?
A. The metal they use is less dense than water
B. They displace a lot of water and contain a lot of air inside the hull
C. Metal is denser than the water and helps it float
D. They cannot float in fresh water, only in ocean water which is denser

# APPENDIX J

**Data Table I: Student Attitude Survey Results – Pre-Treatment (*n*=140)**

| Question # | Mean | Number of Students (%) |
|---|---|---|
| 1 | 3.9 | |
| 2 | 3.6 | |
| 3 | 3.9 | |
| 4 | 2.9 | |
| 5 | 2.6 | |
| 6 | 4.0 | |
| 7 | 2.6 | |
| 8 | 4.1 | |
| 9 | 2.9 | |
| 10 | 3.9 | |
| 11 | 2.8 | |
| 12. Most Interesting | Doing the experiment | 117 (84%) |
| | Seeing the results | 20 (14%) |
| | The directions | 2 (1%) |
| | Answering the lab questions | 1 (1%) |
| | The introduction | 0 (0%) |
| 13. Most Boring | Answering the lab questions | 97 (69%) |
| | The directions | 22 (16%) |
| | The introduction | 17 (12%) |
| | Seeing the results | 3 (2%) |
| | Doing the experiment | 1 (1%) |
| 14. Lab Preference | Labs that tell me exactly what to do | 30 (21%) |
| | Labs that allow me to choose | 110 (79%) |

**Data Table II: Student Attitude Survey Results – Post-Treatment (*n*=140)**

| Question # | Mean | Number of Students (%) |
|---|---|---|
| 1 | 4.1 | |
| 2 | 3.8 | |
| 3 | 4.2 | |
| 4 | 4.1 | |
| 5 | 4.6 | |
| 6 | 4.1 | |
| 7 | 2.4 | |
| 8 | 4.1 | |
| 9 | 3.1 | |
| 10 | 3.8 | |
| 11 | 3.6 | |
| 12 | 2.9 | |
| 13 | Labs that tell me exactly what to do.<br>Labs that allow me to choose. | 35 (25%)<br>105 (75%) |
| 14 | *SK8 Motion Lab*: Enjoyed learning about physics this way. | Yes: 123 (88%)<br>No: 17 (12%) |
| 15 | 3.9 | |
| 16 | Which lab did you prefer? | SK8 Motion: 92 (66%)<br>Hot Wheels: 48 (34%) |
| 17 | *Sublime Lab*: Did you enjoy learning about matter this way? | Yes: 139 (99%)<br>No: 1 (1%) |
| 18 | Which lab did you prefer? | Sublime: 125 (89%)<br>Exo/Endo: 15 (11%) |
| 19 | Which one allowed you to be involved the most? | Sublime: 110 (79%)<br>Exo/Endo: 30 (21%) |
| 20 | *Amorphous Blob Lab*: Did you enjoy learning about matter this way? | Yes: 137 (98%)<br>No: 3 (2%) |
| 21 | Which lab did you prefer? | Amorphous: 112 (80%)<br>Making Silver: 28 (20%) |
| 22 | *Lab*: Did you enjoy learning about matter this way? | Yes: 135 (96%)<br>No: 5 (4%) |
| 23 | Which lab did you prefer? | Build a Boat: 106 (76%)<br>Hope it Floats: 34 (24%) |
| 24 | Which one allowed you to be involved the most? | Build a Boat: 109 (78%)<br>Hope it Floats: 31 (22%) |