THESIS

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SCAFFOLDING EXPERIMENTS IN SECONDARY CHEMISTRY TO IMPROVE CONTENT DELIVERY

presented by

DAVID JAMES JACKSON

has been accepted towards fulfillment
of the requirements for the

degree in
Master of Science in Teaching
Division of Science and Mathematics Education

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SCAFFOLDING EXPERIMENTS IN SECONDARY CHEMISTRY TO IMPROVE CONTENT DELIVERY

By

David James Jackson

A THESIS

Submitted to
Michigan State University
in partial fulfillment of requirements
for the degree of

MASTERS OF SCIENCE IN TEACHING

Division of Science and Mathematics Education

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Abstract

Scaffolding Experiments in Secondary Chemistry to Improve Content Delivery

By

David James Jackson

The focus of this study was an attempt to bring balance to the laboratory approach in a high school chemistry course. Traditional labs have been identified as "cookbook" labs where skills and facts may be reinforced, correct data is verified, but higher order processing may not be required. A greater number of teachers have been turning to inquiry labs also known as "open ended" labs to assess and encourage critical thinking skills, as well as the understanding of concepts within their classrooms. This project was based on the idea that a balance of informational, process and inquiry-based experiments was necessary since not every student is entering high school chemistry is ready to do inquiry-based experiments. My goal was to build a transition from traditional process labs to inquiry labs that would build a confidence in students to pursue higher order thinking and problem solving, while encouraging a greater understanding of concepts. Students need this transition to develop strong foundational skills. The grouping of experiments from lower level cognitive skills to higher order thinking skills is known as **scaffolding**. This grouping would give teachers the assurance that their students were capable of such open-ended inquiry experiments.

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Introduction

I set out to assess the practicality of integrating informational labs, process labs and open-ended inquiry laboratory activities into a standard high school chemistry course. Scaffolding is the process of integrating each of these types of lab activities together to improve learning. An informational lab has a step-by-step procedure prepared for the student to follow. In this lab activity the idea is to expose the student to a chemistry concept, but higher order thinking skills are not addressed. These activities are to improve concept retention and offer hands-on experiences to compliment different learning styles. A process lab, also known as a cookbook or traditional lab, is one in which the student is given a step-by-step procedure to obtain data that can be used to test or illustrate a chemistry concept. Questions are given at the end of the lab to get the student to process the concept at a higher level. The student is not required to understand the reason for the process, but simply follow directions to verify a standard result. The inquiry lab is a laboratory activity where the student is given a problem to solve with little or no direction. The student has to design the experimental approach, conduct the experiment, analyze the data and hypothesize a plausible conclusion. Inquiry labs are the most difficult for the student because of the lack of direction given by the overseeing instructor. Green, Elliott and Cummins reported in their findings that, "*...while students do tend to immerse themselves in inquiry-based projects...they often find it difficult and time-consuming to propose an appropriate research question.*" (Green, Elliott and Cummin, 2004) Most students do not have the necessary skills in a first year high school chemistry course to do this type of higher order investigation. This lack could be due to prior instruction, school curriculum, available hands-on experiences or even social attitudes. Without the necessary background techniques or knowledge, an inquiry lab can be an overwhelming task to some students and even traumatic to some teachers. The students and the teacher need to be certain that they have a minimum set of skills necessary to achieve success. "*It is not always easy to draw the proper balance between introducing the spectrum of learning areas a student needs to experience and provide ample time for discussing, reflecting on, and digesting the material.*" (Howard and Boone, 1997). As I began to research the topic of alternative approaches to laboratory investigations I found it necessary to write a down my findings and thoughts about the necessity of balancing secondary lab experiments. Included in this thesis is a paper (pg. 31) discussing the importance of a proper layout of experiments within the chemistry curriculum.

Rationale

My expectation in this study was to learn how to group experiments that would move students from a skill and knowledge approach into greater critical thinking. This approach would give more meaning to each lab and allow students to work at higher cognitive levels. Better lab activity design should eventually lead to better understanding and retention. The grouping of experiments from lower level cognitive skills to higher order thinking skills is known as scaffolding. This grouping would give teachers the assurance that their students were capable of such open-ended inquiry. This approach was also noted in an article by Thomas R. Tretter, (2000), Physical Science Lab Essentials, *"Students bring their skills up to speed with a logical sequence of activities."* Students are not always from our district and may have differing amounts of background knowledge & skills, so we can never be certain of each student's scientific background. How can we move our chemistry students in the direction of inquiry based labs where they will be required to design and evaluate their own experiments, when we are not positive of each person's skill or knowledge level? *"The context of a course is perceived differently by students and teachers, because their experiences, knowledge, goals and motivations are different."* (Carter and Brickhouse, 1989). I was disappointed with students conducting labs in which they simply followed a set of steps, filled in some blanks and within minutes could not explain the purpose for the experiment. In this project laboratory skills are first strengthened through a set of process or informational labs with greater teacher involvement. This background knowledge would ensure the teacher and students that they have acquired the minimum skills to work on labs where there is little to no teacher involvement. Once appropriate background skills are introduced and practiced the students are given self-directed inquiry labs. Scaffolding is the process of putting laboratory experiments to a logical sequence that develops & strengthens students' skills, and then these primary activities are followed by a more challenging inquiry, problem-based activities. The overall outcome would be students who have science understanding similar to the scientific community.

Community Profile

The community of Eaton Rapids is located 12 miles south of Lansing, Michigan. It is a rural community of about 5000 citizens within the town and 10,500 within the school district boundaries. With very little industry, most growth is due to serving as a bedroom community for employers in the Lansing area. A North Central Accreditation survey noted that the three major employers of residents were, The Buick/Old/Cadillac Group, State of Michigan and Michigan State University. The main sources of income for residents could be divided in to six categories.

Technical 30%

Managerial/Professional..............15%

Sales.....................................25%

Miscellaneous........................20%

Service..................................20%

Farming................................2%

School Profile

The district supports (3) Elementaries for grades $1^{st} - 4^{th}$, (1) Intermediate building for grades $5^{th} - 6^{th}$, (1) Middle School for grade 7^{th} - 8^{th} and (1) High School for grades $9^{th} - 12^{th}$. There were 1074 students enrolled in the high school during the year of this project. Of those enrolled, the composition of the student body was; (52.5%) Male, (47.5%) Female, (95%) Caucasian, (5%) Minority.

Class Profile

A total of 24 students were in the introductory chemistry course, but data was collected for 22 students. (8 male and 14 female) Others had either dropped the course or had not completed the required paperwork to allow their work as part of this project. A counseling department based on individual scheduling, actually determines the composition of the classes. The students in this class represented the broad spectrum of academics and social-economic backgrounds as diverse as Eaton Rapids itself.

Implementation

In general secondary chemistry courses are designed to train students to be scientific thinkers. Scaffolding* was designed to allow the students to experience lab activities at each of three levels to improve their chemistry understanding and retention.

* See Abstract for full description of Scaffolding

To achieve scaffolding I inserted some new labs into the current method of content delivery I had been using in the past. I chose process and informational labs that would help build laboratory skills, such as proper instrumentation use and data collection. These labs familiarize students with the laboratory setting. They demonstrate necessary experimental procedures the student would need to know to attempt the inquiry lab later in each unit. The information labs were chosen based on positive student responses in the past. The inquiry activities chosen or written were selected based on the earlier labs conducted in each unit. For example, if density determination was practiced in a process lab, the inquiry lab, later in the unit, would also require density to be determined for an adequate conclusion to be drawn. The student should be able to use their previous lab experiences as a starting point for the open-ended investigation.

The content of this work covers three chapters in our first year chemistry course. The topics included matter, energy and atomic structure. In previous years, this amount of material required about 7 ½ weeks to complete formal instruction, laboratory activities and assessments within a 55-minute class period. With the introduction of the scaffolding approach, the time line increased to 10 ½ weeks.

The following is a week-by-week lesson plan to show the placement of the labs and the overall amount of time spent on developing the scaffolding. Most of the daily lessons included a discussion time, a reading, and then an assignment from the text. Each day listed identifies the concept or idea presented in class.

Week #1

Class/Thesis Introduction

Graphing Rules/Assign.

Book Work; Refresher math

Lab Check in/ Lab Safety

No School

Week #2

Labor Day

Scaffolding Pre-Test (*1)

Class Syllabus/Science Equipment Intro.

Lab: What is it For? (*2)

Matter/Element Quiz

Week #3

Writing Proper Lab Reports

Physical Properties of matter

The Scientific Process

Lab: Scientific Process (*3)

Finish Lab/Equipment Quiz

Week #4

Density: Problems/Graphical

Chemical Properties of matter

Chapter Review: Matter

Lab: Density Lab (*4)

Discussion of Chapter Review, Matter

Week #5

Test: Matter

Lab: Ident. Of Unknown Metal (*5)

Lab: Ident. Of Unknown Metal

Computer Research for Report

Types of energy

Week #6

Computer Research, Densities of Unknowns

Demo: Endothermic vs Exothermic (*6)

Heat/Temp/Calorimetry

Model Problem Solving/Video

Lab: Heat of Fusion of Ice (*7)

*1- See appendix: Item A
*2- See appendix: Item D
*3- See appendix: Item E
*4- See appendix: Item F
*5- See appendix: Item G
*6- See appendix: Item H
*7- See appendix: Item I

Week #7

Energy Concepts

Calorimetry Problems

Model Problem Solving

No School/Conferences

Energy Chapter Review

Week #8

Discussion of Chapter Review, Energy

Energy Test

Lab: Unknown Food Calories (*1)

Calorie Lab

Calorie Lab Research

Week#9

Development of Atomic Theory

Ob-sertatiner Lab (*2)

Scientists of the Atomic Model

No School/Power Outage

Video: Atomic Model

Week #10

Electromagnetic Radiation

Mystery Box Lab (*3)

Isotopes, Mass No#, Atomic Mass

"The Atom" Chapter Review

No Classes/Professional Development

Week #11

Light Lab (*4)

Discussion of Chapter Review, Atomic theory

Atomic Theory Test

Scaffolding Post Test (*5)

*1- See appendix: Item J *2- See appendix: Item K *3- See appendix: Item L
*5- See appendix: Item B

Scaffolding Activities

The following is a description of each lab and its relation to the content.

Unit 1: Matter

What is it for? Laboratory Equipment (Appendix: Item D)

This is a newly designed informational lab where the student determines energy and mass changes in water heated by a candle. The student is exposed to basic chemistry equipment such as graduated cylinders, beakers, thermometers, balances, ring stands and safety equipment. The concept of error and degree of accuracy involved in each type of measurement is also introduced.

Scientific Process (Appendix: Item E)

This is a newly designed process lab that addresses the scientific approach. The student questions, hypothesizes, experiments and concludes why salt aids in the melting of ice. Students write down their predictions of what they think will happen to the temperature of a container of ice when salt is added. They run their experiment along with a control and make careful observations. They then discuss their findings in a conclusion along with a hypothesis of what they believe is the scientific basis of their data. This is the first chance students are given to engage in critical thinking.

Density Lab (Appendix: Item F)

In this process lab the students determine the density of a liquid and an irregularly shaped solid. The student is exposed to more organized data collection, volume by displacement and calculations with error analysis, which will be necessary for the inquiry lab in this unit. They are required to identify the unknown metal from a list of densities. Accuracy and precision is stressed.

Identification of an Unknown Metal (Appendix: Item G)

This is an inquiry lab where students are in the role of a company chemist. They must identify metal samples and suggest a mining focus for the company. Students run a bench density analysis on unknown metal samples and put their previous lab and math skills to use. They run a library/internet research on each metal to determine its cost effectiveness to mine. Price and demand are of prime importance. Many metals are very close in density and sometimes students need to repeat their experiments to make sure of their findings. Finally, they draft a report to the company geologist summarizing their data and suggest a possible course of action that is in the company's best interest.

Unit 2: Energy

Endothermic/Exothermic Demonstration (Appendix: Item H)

This is an informational demonstration showing the difference between exothermic reactions and endothermic reactions. The lab helps to reestablish the idea that exothermic reactions release energy causing an increase in temperature and endothermic reactions absorb heat, lowering temperature.

Heat of fusion of Ice (Appendix: Item I)

This is a textbook process lab in which the student determines the heat of fusion of ice. This lab introduces the concept of specific heat capacity, energy changes during phase changes and energy calculations. The student is introduced to, energy changes during phase changes.

Calorie Determination of an Unknown Food (Appendix: Item J)

This is an inquiry lab that allows students to analyze the calorie content in various foods. Students are sent a new food sample from the "company" for final analysis. They are to compare the new food sample to other food samples and determine its calorie content. Students are to recommend a name for the food, suggest serving size and product placement.

Unit 3: Atomic Theory

Obs-Certainer Lab (Appendix: Item K)

This is process lab that allows students to make indirect observations using simple plastic trays with various internal partitions. The students tilt the tray and by listening to the sounds they make inferences into the tray's interior design. The purpose is to teach students to make observations without the use of sight and draw conclusions from these indirect observations. Students are allowed to open the trays to check their predictions.

Mystery Box Lab (Appendix: Item L)

In this newly designed inquiry lab activity, students determine the contents of a box using only indirect observations. Students must analyze, discuss & predict the contents and their arrangement within the box interior. Students are even able to separate parts of the box, which leads to more detailed observations. The lab encourages complex thinking skills. Students allowed to run the experiment as many times as they wish, but the boxes are never opened, so students can never directly verify if their predictions. This leads into the discussion of the idea of the atom and how science has determined our atomic model through indirect observations.

Light Lab (Appendix: Item M)

This is a short informational lab designed to show students the spectrums of various elements and lead them to the understanding of how light is created. They get to view and sketch the spectrums of several elements and answer a few simple questions about light and why each element has a unique spectrum.

These laboratory activities were the tools I used to implement this study. Their arrangement was based on the idea of scaffolding. A pre-test was given to each student prior to the study to determine student knowledge at the beginning of the study. Upon completion of these units a post-test was administered to measure acquired knowledge. In mid November the class moved on into other chemistry topics and again at the beginning of May the students were given a retention test to measure their long-term retention of the topics presented in this study. These pre, post and retentions tests were the tools I used to collect the data in the following section. Each student was randomly assigned a number and scored. The data is broken down into pre and post-test questions with each student response listed in a table. An average score for each response was tabulated to determine overall change in student knowledge. Tables of these scores are available in appendix item #10.

Students were assessed in this study by four major components.

1) **A pre-test** (Appendix: Item A) to check students' existing knowledge. The test consisted of nine questions, each one aligned to the units presented in this paper.
2) **A post-test** (Appendix: Item B) to measure the changes in students understanding based on the concepts presented. Nine questions similar to the pre-test, but with slight variation to not be identical. Then the final survey question to again check student attitudes towards inquiry science.
3) **A retention test**, (Appendix: Item C), which was designed to measure the retention level of each student comprehension after a specific amount of time has elapsed since the material was presented and tested. Five questions designed to mimic the pre and post questions and check long-term retention.
4) A **survey question** was included in each pre and post -test to measure student confidence inquiry science lab activities.

Evaluation

The assessments were designed to check incoming knowledge of each student and provide a level of comparison to the knowledge accumulated from the new teaching style presented. The post-test would determine the new level of understanding and the retention test was designed to measure knowledge after a length of time had past. The survey question was designed to measure individual changes in attitudes towards science as the course progressed.

As we continue in this discourse, I would like to clearly define my goals when evaluating this unit:

1) Measure and evaluate how scientific understanding is affected by implementing the scaffolding process within the secondary laboratory setting.
2) Measure and evaluate how the retention of knowledge is affected when the scaffolding process is implemented within the laboratory setting.
3) Measure and evaluate any changes in student attitude towards chemistry when the scaffolding process is implemented within the laboratory setting.

To evaluate scientific understanding, each test question was scored based upon a rubric of points for specific responses. Averages for correct responses were calculated for each test item and then recorded for comparison purposes. Finally *t*-Test results were run to see of the Null Hypothesis could be rejected for aligned pre and post-test items. We determined our "*p*" value parameters based on the *t*-Test for each pre and post-test pairs to be (+ 0.05). For a "*p*" value < 0.05 the data is considered statistically different. For a "*p*" value > 0.05 the data is considered statistically the same.

The following table is provided as a quick overview of the results. Complete results of individual student scores for each question on the pre and post-test are located on pages 83-87 of the appendix.

Table 1: Data Overview

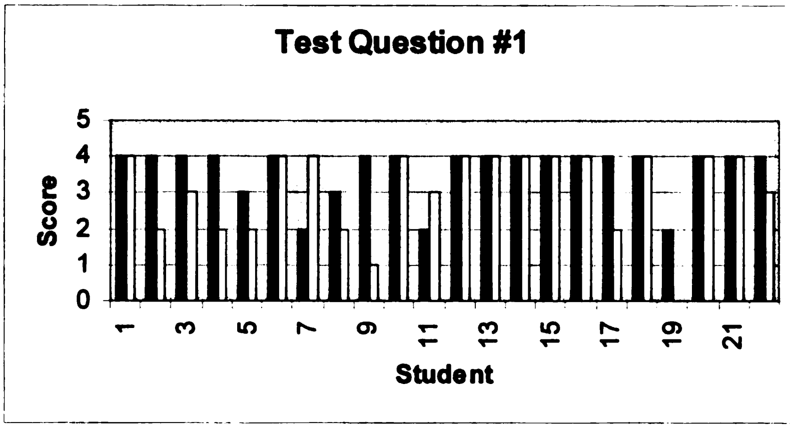
Question	Pre-test Avg. score	Post-test Avg. score	Average change	"*p*" value result	Chemistry concept
#1	3.64	3.24	Decrease	0.66	Equip. Ident.
#2	2.18	1.76	Decrease	0.009	Equip. Usage
#3	2.50	3.24	Increase	0.019	Equip. Set up
#4	3.14	2.24	Decrease	0.001	Science Process
#5	2.32	3.00	Increase	0.027	Density
#6	1.55	2.62	Increase	0.006	Density Calc.
#7	1.64	2.14	Increase	0.012	Accur./ Prec.
#8	0.82	1.67	Increase	0.007	Endo/ Exo
#9	0.91	0.86	Decrease	1.00	Calorimetry
#10	2.41	3.24	Increase	No Data	Survey

The data above indicated that there were significant gains in the areas of equipment identification in setting up a lab, density concept , density calculations, accuracy & precision and endothermic & exothermic. There were no significant changes in equipment identification and usage, science processing and calorimetry. These decreases are discussed and explained later in this evaluation.

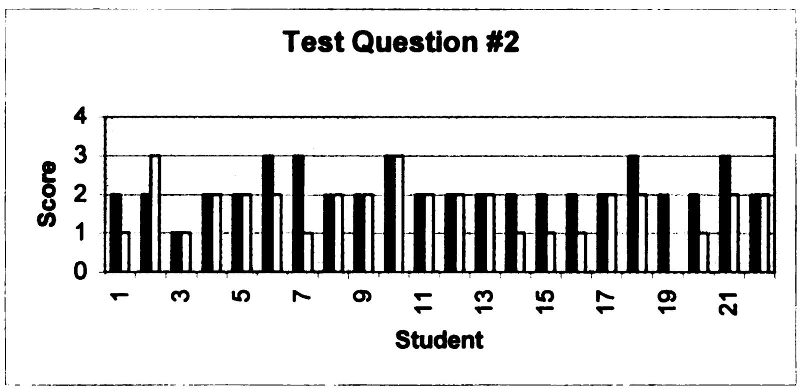
The following charts of individual scores were created for each aligned question pair to allow for a visual comparison of each student's progress in the study. Each question on the pre-test that coincides with the post-test are placed together so a comparison can be made of the new teaching method implemented in this study. Below each graph the average score on the pre and post-test is listed for the entire class. The reader can then see whether the class improved on the test item after instruction had taken place. The pre-test score is indicated by the solid dark bar and the post-test score is indicated by the white bar. A quick overview can also be made to which students scored higher on the post-test after instruction had taken place since each student is identified by a number 1-22.

Figure #1 ***Reponses to Pre/Post Questions #1-3***

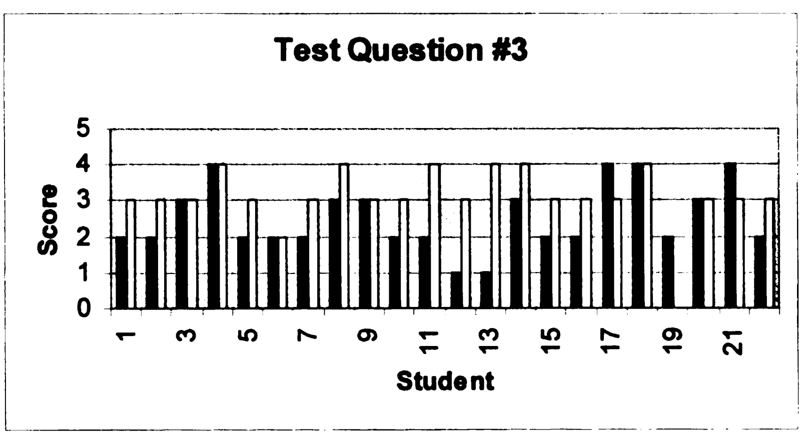
Solid Bar: Pre-Test White Bar: Post Test



Average Score Pre-test: 3.64 Post Test: 3.24

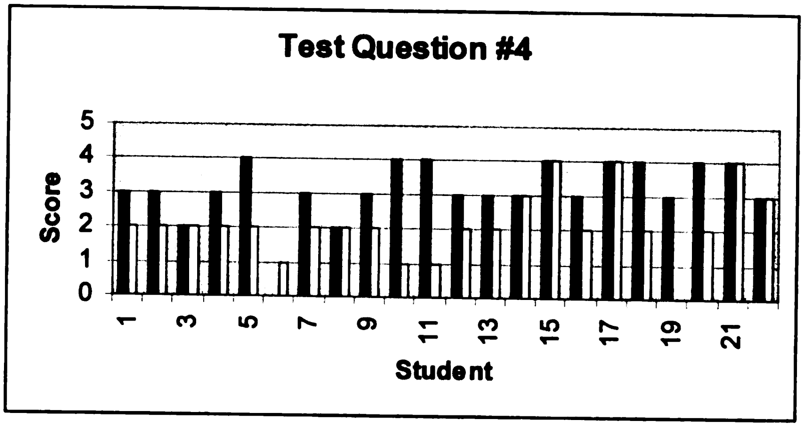


Average Score Pre-test: 2.18 Post Test: 1.76

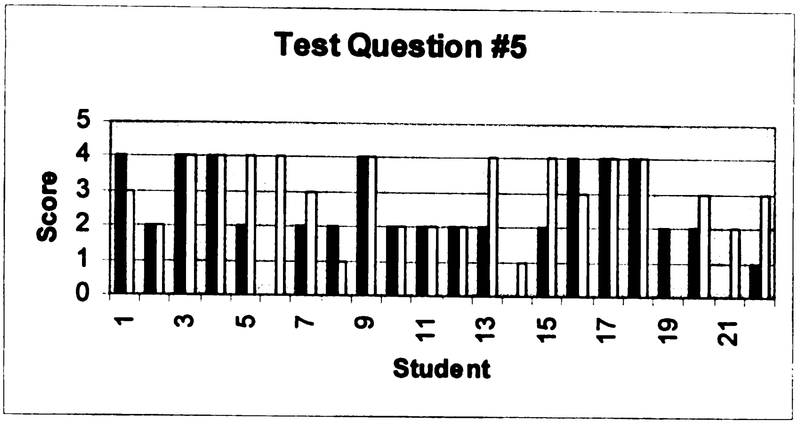


Average Score Pre-test: 2.50 Post Test: 3.24

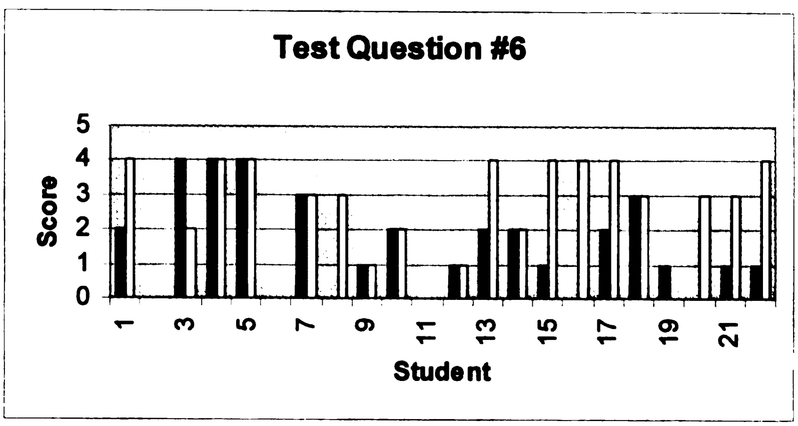
Figure #2 ***Reponses to Pre/Post Questions #4-6***



Average Score Pre-test: 3.14 Post Test: 2.24

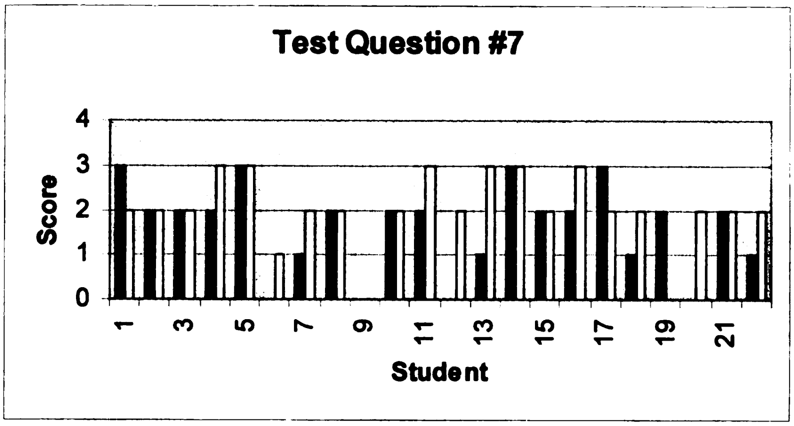


Average Score Pre-test: 2.32 Post Test: 3.00

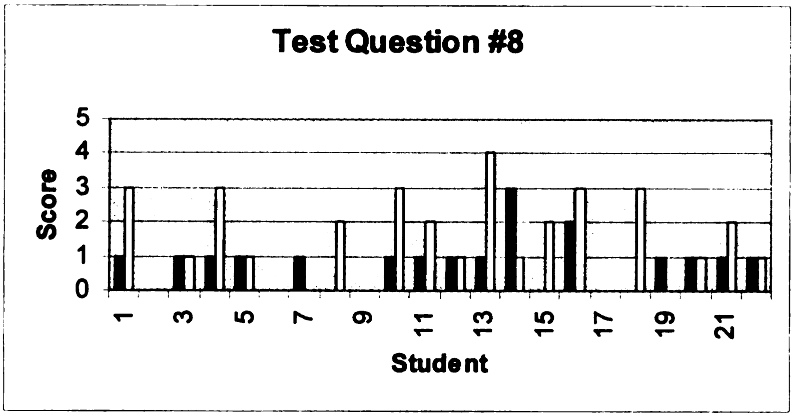


Average Score Pre-test: 1.55 Post Test: 2.62

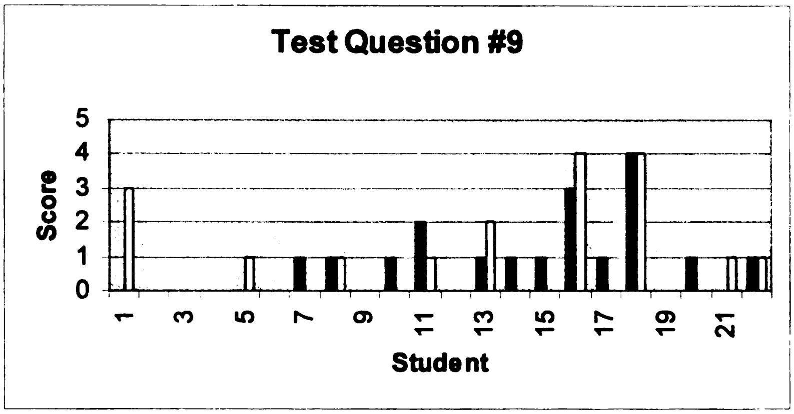
Figure #3 ***Reponses to Pre/Post Questions #7-9***



Average Score Pre-test: 1.64 Post Test: 2.14



Average Score Pre-test: 0.82 Post Test: 1.67



Average Score Pre-test: 0.91 Post Test: 0.86

My first goal was to measure and evaluate the improvement of scientific understanding of the students involved in this project. I noticed an overall increase in their abilities to approach the concepts more scientifically. The majorities of the testing showed the students made some real gains and were able to grasp the chemistry concepts at a deeper level. Students had shown gains in the basic skills of Equipment usage, test item #3. They were able to identify and decide what items were necessary for a laboratory activity. In the past, they would take one of each item on the supply table, even if their lab didn't require the equipment. Now they were demonstrating the skill to evaluate the equipment's use and decide if it was necessary for the investigation at hand.

The concept of density is also traditionally taught in the first week of most high school chemistry courses. Even when most students are exposed to the concept of density at an early age, I have found many students lack the full understanding of density both, conceptually or mathematically. They showed improvement in their scores in both these areas as test items #5 and #6 show. Students were able to distinguish the differences between density values for various objects and correctly determine what a larger or smaller density value means. Mathematically the students were also stronger. They were able to state how to determine density and comment on it usefulness for identification within the science field. They began to understand the value of density when they needed to identify various unknown metals. This greater understanding of density was evident in their scores.

The final two areas the showed improvement was item #7, Accuracy vs. Precision and item #8, Endothermic vs. Exothermic. The need for quality data became evident to them when they were identifying unknown metals. Without accurate values a correct metal could not be easily selected from the list since many metals have densities that are very close in value. Students began to address their poor lab skills to improve the data they were collecting and a greater focus on technique was evident. Students knew better laboratory skills equate into better density values. Better values lead to easier identification. The definitions of "endothermic" and "exothermic" are commonly switched around and easily mistaken by students. Their increased scores on test item #8 proved they began to grasp the concept that temperature changes accompany energy transfers. Students could identify endothermic changes create decreases in temperature while exothermic changes create increases in temperature.

As the unit progressed I note that students began to show improvement in their approach to the laboratory activities and for the most part they became more actively involved in the learning process. I was excited to see them take more initiative in their learning. The laboratory portion of the chemistry class began to show greater relevance and greater enhance the learning taking place in the students. Quickly followed recipe labs were replaced by investigations that encouraged the students to participate at level I had not experience before. I began to see the changes I have been looking for in the laboratory. Students were experiencing true scientific growth. They were thinking, discussing and investigating problems as a scientist would, there was less standing and waiting and more students were seeing differences and experiencing difficulties that had to be either fixed or explained. No more passive learning. Science was happening.

My second goal was to evaluate the students' ability to retain their knowledge for a longer period of time. In early May I gave a short retention test of five questions. Four were aligned directly to the pre and post-test and the final question came from the material on light that I had taught in this project. The retention test can be seen in appendix item C and individual student scores are noted in Tables #1-7 of the appendix. The five items tested were: equipment set up and use, density calculations, endothermic/ exothermic concepts and accuracy vs. precision of scientific data. The following chart shows the average score between the aligned items on the pre, post and retention test.

Table 2: Pre, Post and Retention Test Average Class Scores

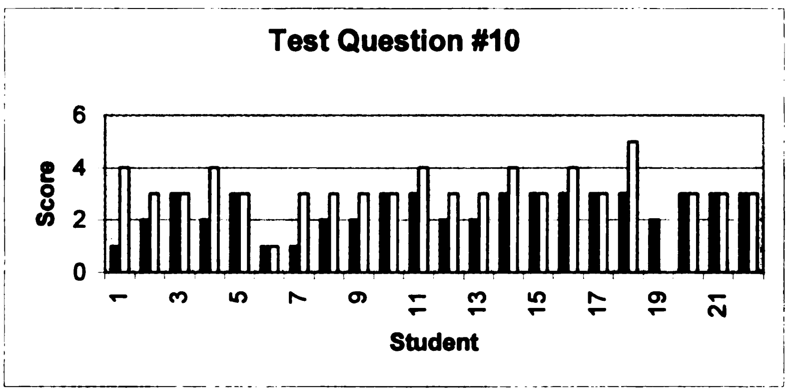
Retention Test No#	Chemistry Concept	Pre/Post Test item	Pre-test Avg. score	Post-test Avg. score	Retention Avg. score
1	Equipment usage	#3	2.50	3.24	2.60
2	Density Calc.	#6	1.55	2.62	2.55
3	Light	Not aligned			1.70
4	Endo/Exothermic	#8	0.82	1.67	1.35
5	Accur/Precision	#7	1.64	2.14	2.95

The retention test showed strong gains in long-term retention. When students were tested months after instruction took place, they were still able to make sound logical responses to previously taught scientific concepts. Item number 5 of the retention series showed still another increase. This was because successive lab activities in later chapters required accurate data. Students had been still practicing accuracy and precision even after the project material had ended. There was a decrease in the average scores, but this is to be considered normal for the time that had passed. Most students were able to either correctly or partially respond to the questions. They were showing signs of retention.

This was also evident in the class. When previous topics from the project material were used to bridge understanding to new concepts being presented, students were able to answer more background questions. Recall was better and less time was needed to develop concepts and the class progressed forward at a better rate. I was impressed with how the students were doing in the long run. Scaffolding was doing what I had hoped it would for the students as well as for the class as a whole. Teaching was more time consuming by incorporating inquiry labs, but the result of better understanding on the students' part made for better discussions and stronger foundations for future topics.

My final goal was to assess the students' confidence in science. I used a survey question on the pre and post-test to assess student confidence. I had experienced a large amount of apprehension in the chemistry class in the past. Numerous students professed to being afraid of chemistry and not liking science. I felt this was part of the reason why some students never truly put forth a full effort in chemistry. If they think they cannot do something, they tend to live up to their expectations, regardless of our expectations for them. The pretest survey checked student confidence to scientifically answer an unknown problem. The post-test survey showed a 24.7% increase in student confidence. Every student either stayed the same or showed an increase in confidence. Figure # 4 shows a chart of student changes in confidence as the project progressed. Their confidence was measured in the pre-test then again in the post-test after completion of the project.

Figure #4 ***Reponses to Pre/Post Question #10***



Average Score Pre-test: 2.41 Post Test: 3.24

Students were allowed to freely respond after the survey question to clarify their rating of their confidence to solve an unknown problem. Here are a few of the responses.

- *"It doesn't hurt to try, yet you never know if you can come up with an answer. If everyone could come up with an answer there would be a lot of things that would be curable."*

- *"It would be easy to get info from anywhere, but knowing it hasn't been attempted make it difficult."*
- *"If you can get help from anyone you should feel pretty confident."*
- *"It depends on the problem."*
- *"I think I could do it, but it would be very difficult to come up with the methods and try to solve the problem"*
- *"Given the proper resources, a good amount of time, I would give it a try."*

With the overall results and responses given by the students I feel very confident in the scaffolding approach to laboratory investigations. Given a little more time and adjustments, I believe that this guided approach to inquiry problem base laboratory approach is a successful way to improve scientific thinking in our secondary high school chemistry. It would make the investigative portion of chemistry take on new relevancy and instill more confidence in our upcoming scientists.

Anomalies in Data

As I began to tabulate the data, I realized there were some correlation problems between the pre-test and post-test results. Some of the results were revealing a poorer student performance after working through the designed curriculum. Each of the pre and post-test question were directly aligned as mentioned earlier. If item #1 on the pre-test addressed equipment identification, then item #1 on the post-test was also on equipment identification. According to my hypothesis, a decrease in the % of correct responses on the post-test should not have been the case. After further investigation I began to realize there was a problem with the questions I chose to assess student knowledge.

In question #1 on the pre-test I chose common laboratory equipment to be identified, a graduated cylinder and beaker. However, in the post-test question #1, I had chosen two pieces of equipment I believed were common, but one had not been used thus far in any of the investigations we had done. So identification and recognition relied on memory from a basic review, and not from hands-on use. This may have been the reason for the slight decrease in correct student responses. The pre-test posted a 3.64 average score response, whereas the post-test posted a 3.24 average score. This small change was most likely due to the error of the equipment I selected to be identified. Labs that that required the use of a clay triangle were not conducted during the project trial period. The iron ring, which was frequently used in our project laboratory activities, was easily identified on the post-test. This accounts for the small deviation in the first testing item.

A similar problem arose on pre and post-test item #2, description of equipment use. The graduated cylinder posed no trouble for the majority of the class; knowing it is used to measure the volume of various liquids. The pre-test average was 2.18 and the post-test 1.81. The watch glass, the focus of question #2, had not been used in the experiments we conducted to this point. Thus, students didn't acquire first hand experience on the uses of a watch glass within the laboratory setting. The "*p*" value for question #2 based on the Null Hypothesis was 0.009, within our parameters, but there was an overall decrease in correct responses. It is when a student actually uses the equipment they can truly understand its usefulness. Without laboratory exposure I would assume most students would not be able to adequately explain its role in laboratory experiments even if they were introduced to it in lecture.

Another anomaly occurred in question #4. The Pre-test simply asked for a description of the steps scientists use to solve a problem. When I wrote the post-test I disguised the same question using real-life occupations. The "*p*" result was 0.001, but the overall correct student responses decreased. They students were asked the set of steps a veterinarian, doctor, biologist and chemist would use to conclude why a large group of deer had died. Instead of the steps, the students provided examples of job descriptions. They were correct in their responses, just not in-line with my response expectations, describing the general steps in the scientific method that all scientist use when approaching a problems.

The same problem arose in question #9 on calorimetery. Students performed poorly on the pre-test, so I made a strong effort to clarify the difference between calories and fats. However, with all the public information about eating, diets and fats, it was extremely hard to change student ideas. Many answered the questions based on popular information, but few were able to make the transition to a chemical viewpoint. Most answers centered on the dangers of fats, whereas I was seeking a response to the energy required to break those fats down.

At the end of this evaluation I learned that the questions presented in any teaching situation have to be well defined. Wording that may seem clear in the teacher's mind may be very easily misinterpreted by the student. It was in the wording I believe many of these anomalies occurred. The project, based upon the data and the changes I saw in the students' scientific thinking and behavior, was a powerful learning experience. This project has dramatically altered my direction of teaching. Upon evaluating this data I believe this new laboratory approach will significantly impact the students I will encounter in the future. In the future, I would focus on the questions presented to make every effort so they cannot be misinterpreted. I realize that this is a difficult task and every question can be misunderstood, but with all I have learned through this project I believe I could create questions that would better clarify the response being sought.

Discussion and Conclusions

My goal in this entire process was to learn if by arranging the experiments in the lab from traditional, basic skill labs, to more open-ended inquiry labs, that this form of instruction will improve understanding, retention and attitudes towards secondary. In the past I have come across many students who view laboratory activities as "boring" and "irrelevant". Numerous students seemed passive and willing to let the students labeled as "smart" or "intelligent" do the majority of the lab work and follow-up report. These students who were able to let others do the work, would label themselves verbally as "dumb" or "not very good in science". This allowed only a select number of students to benefit from the learning that was available in the laboratory setting. My desire was to build into each student's understanding that they can "do" science and that they are capable of significant scientific thinking. I believe that this study was successful in revealing that students are capable of scientific thinking, but they must be prompted and guided into this type of work. Inquiry problem based science is not the norm in most high school settings, but with the scaffolding students can be taught to process at these higher cognitive levels and be taught to think more scientifically.

As I reflect over the course of my work I began to realize the scope of my project. I set out to improve the instructional delivery within the laboratory environment. As a whole I believe that the inquiry, problem-based approach to laboratory instruction is an important restructuring that needs to occur within the secondary high school lab setting. I found this type of instruction challenges the students. Many were not at all remotely used to being left to forage through their scientific background to develop a focused hypothesis and effectively pursue it experimentally. As they began the arduous task of self-dependence and began to use all the possible resources available to them, I saw growth in the use of their scientific processing. I could see them working together and the questions they were asking during laboratory activities were more guidance rather that blind help. Instead of "What do I do now?" they began to ask, "Could we do this." They were coming up with their own suggestions and not relying on me for as much direction. I enjoyed watching the students together bring in the own piece to solve the puzzle that lay before them.

What I learned was that students will not reach deep into themselves to create an adequate problem solving schematic unless driven by an outward problem. As a product of traditional formalized instruction it has been difficult to leave the highly ordered, step-by-step, process labs. These labs are easy to predict, easier to guide and leave very little room for error and unknown possibilities. They are like the consistent nature of an old friend, "you always know what they will do". Traditional labs are easy to set-up, take less time to work through and the results are very consistent. However, these labs do not always develop the scientific thinking students need. This is where inquiry lab activities come in. Without the discovery aspect of the inquiry labs, the evolution of scientific thought by individual students would not develop. As a result, I am currently trying to bring more open-ended activities into my instruction, both within the laboratory and within the classroom presentations. These activities are key to helping the students discover the true "process of science". How can we ever expect them to become pure scientists if they are new given the chance to fly under their own abilities? *"I think that developing imagination, scientific creativity, and intellectual autonomy is far more important that the accumulation of cold knowledge."* (Gallet, 1998).

In reflection, I have come to see my teaching develop in ways I never thought possible. This research has opened me up to a greater passion and desire to see the instruction within my classroom become a type that will develop and foster new scientists. Scientists that have the capabilities and attitudes to solve problems and research ideas they never thought possible.

Scaffolding Lab Activities to Improve Science Learning and Retention

I. Statement of Problem and Rationale

The purpose of this research was to determine the effectiveness of organizing laboratory experiments, from basic skills to open-end student driven labs, to concept retention and attitude toward science inquiry.

II. Need for format driven labs.

A. Traditional labs allow students to practice experimental techniques.
B. Traditional labs produce good, not necessarily good scientists.
C. Memorizing information without assimilating it.
D. Sterilizing imagination and initiative with recipes.
E. Moving away from process labs.

III. The value of inquiry labs

A. Using higher order Bloom's taxonomy.
B. Investigative experiments enhance student learning.
C. Students must participate in the pedagogical process.
D. Inquiry takes longer.
E. When is enough enough?

IV. Bridging the gaps between skill labs and opened labs

A. Is there enough background to build upon?
B. More work getting in, but learning is higher.
C. Balance is better

Building Balance in the Chemistry Laboratory

Laboratory instruction has always been regarded as an important component of the secondary science curriculum. *"Although researchers have found it to possess the potential for enriching the formation of science concepts by fostering inquiry, intellectual development, problem-solving skills, and manipulative skills, it often fails to reach its full potential."* (Hofstein and Lunetta, 1982). In my course I felt the same way. The lab activities were filled with a wealth of information and each was well correlated to the concepts presented in our chemistry book. Textbooks supply labs that are well aligned with each chapter allowing theory to be applied in a practical way. Even with this good correlation, I had to agree that my labs were not impacting the students to the degree that I would like. *"My students could turn out as good cooks, but not necessarily good scientists!"* (Gallet, 1998). During my research, I found many papers recently written on the impact of inquiry based laboratory experiments at the secondary level. I will refer to many of them as I develop this paper. More and more of the articles began to draw a poor picture of the use of traditional laboratory experiments, because of their lack of use of higher order cognitive thinking skills. I knew these traditional experiments, although cookbook style in nature, are still key to developing necessary skills. *"Recipes and procedures are a point of departure; used thoughtfully, they can develop skills and provide insight. What's wrong with cookbooks? Nothing!"* (Addison Ault, 2002) There needs to be a balance, but where is it? My hope was to find a series of experiments that would take the each person in my lab from student to scientist, from cook to researcher.

Within the scope of this discussion I will present the need for both traditional and inquiry lab exercises.

I. The Need for format driven labs.

A. Traditional Labs allow students to practice experimental techniques.

Traditional labs have been the mainstay of secondary science for years. Many teachers today are products of this teaching style. Many students are still working out of lab manuals that are primarily cook-book style experiments. The students follow a step-by-step procedure with diagrams to obtain some consistent data that is standard for that type of laboratory work. They record this data into a provided table or chart. Calculations may be necessary to arrive at the final numerical outcome and usually the equation is provided. The challenge for the student comes at the end in the form of questions. A series of questions are posed with the expectation that greater understanding of the concepts being explored will be developed. Sometimes an explanation of the lab results may be required or a comparison to a known scientific result may be made. The expectation is that the student will understand how the lab experiment ties into the current subject matter being taught in the classroom. Whether or not this truly happens within the mind of the budding scientist may not be important as the skills being acquired in the laboratory. Earlier labs within a course should be geared towards building and practicing lab skills. Only lower level scientific thinking skills should be addressed in these introductory labs until the important lab skills have been fully developed.

> *"Beginning high school students may not have a firm foundation in the prerequisite skills to succeed in a laboratory-oriented science course, yet they are expected to develop these skills and a years worth of scientific literacy by the end of the course. Science teachers are therefore faced with the task of not only teaching the content mandated by the accountability scheme but also with teaching many of the prerequisite skills necessary for students to succeed in a lab science"* (Tretter, 2000).

A technique or skill can prove to be much more important than the concept itself. This is not to put content learning into a secondary role, but basic skills are important! Sports can demonstrate this point quite well. Even though an athlete will need to understand the rules and strategies of the game to succeed at all levels, they first need fundamental skills to be an effective player. Intelligence without ability, is of little use. A student may be able to calculate density, but they need to be able to measure the mass and volume of an object first. Traditional experiments build these important skills. Technique requires practice to be strengthened and sharpened. Basic skills such as reading thermometers, balances, graduated cylinders, decanting, filtering, heating and numerous other common laboratory techniques need to be honed. Without quality lab skills students will continue to get poor results and which will hinder their ability to draw adequate conclusions even from insightful inquiry labs.

B. Traditional labs produce good results, not necessarily good scientists.

The goal of all lab work within the science curriculum is to link theory with actual experimental results. Laboratory experiments take conceptual knowledge and bring it to life with practical application. These activities are traditionally designed for students to gather data with good precision, have a high likelihood of success and get results that are less controversial. This is not true for real science. Research and developers explore unknown avenues of thought, exploring hypotheses that could lead to a dead-end, yet still hoping to learn from unexpected results. Secondary science has stayed away from this type of approach. We design labs that are easy to prepare, grade and are time efficient. In cookbook style labs everybody does the same thing, the lab is easier to supervise, the outcome is known by the instructor and relevant to the lecture. Where is the creativity, the discovery? Secondary science has the dubious task of teaching content and basic skills. Focusing on skills may produce good results, not necessarily good scientists. *"Without well-reasoned teacher intervention in both the design laboratory structure and its implementation, students rarely develop understanding similar to that of the scientific community."* (Clark, Clough, Craig, 2000). As educators we work to develop deep and long-term understanding in students. Trying to instill in them the ability to process and act as a scientific thinker. Traditional process labs are good at building foundational laboratory skills, but are they creating the type of scientists we need in the future? Research shows that laboratory experiments are not fulfilling the purpose for which they were designed. *"Laboratory activities, as they are currently being implemented, do not enhance students' learning or understanding of science."* (Hoffstien and Lunetta, 1982). Other researchers, Lazaworitz and Tamir, 1994, support these findings. As we begin to change our focus to encouraging the evolution of the scientific processing in students and less on the exactness of their data, we should begin to see scientists emerging form our classes.

C. Memorizing information without assimilating it.

Although teachers place significant value on the laboratory experience, they sometimes do not implement the tasks in a manner that facilitates the type of learning desired. *"...In most cases the laboratory investigation is intended to confirm something that has already been dealt with in a expository type lesson. Students are usually required to follow a recipe in order to arrive at a predetermined conclusion. As a consequence the cognitive demand of the laboratory tends to be low."* (Tobin, 1987). To become retained knowledge, information must pass through the cerebral cortex, integrate into the twisting web of neurons and ultimately find its resting place within the reaches of the student memory. This is to say, "When are the students going to own what we teach them?" The ownership of knowledge is much different that its use. We need to understand how knowledge is transmitted and how it is assimilated.

Gallet (1998) reminds us of the findings of St. Jean's (1994) work, *"Traditional teaching creates surface or superficial learning, characterized by high levels of memorization and student dependence on the professor for the distribution of work. Students retain little of what they learn and have difficulty applying what they know."* The memory can be a place of simple short-term storage with little chance of recall at a later time. To regurgitate some minute fact on an exam for a specific grade is the overall implication for the science course. Our chemistry laboratory courses need to be more than a requirement on the path to a higher degree. Students need to see and experience a scientific growth within themselves. They need obtain an ability to develop thoughtful questions and confidence at formulating the steps to discover the solutions they desire.

D. Sterilizing the imagination and initiative with recipes.

Getting the "A" does not mean as much as it did. Students can learn how to function within a system and know how to achieve a specific score, yet not truly understand the concept presented. Traditional experiments can be easier for the student in the short term, but have little effect in engaging scientific processing on the student's part. Teacher may find these labs easier to conduct and students are more successful with these structured labs, but what are they missing? Students find these labs boring, inflexible, lacking discovery, easy to manufacture data, simple to copy, lacking creativity and do not learn relevant problem solving skills. *"...freedom to explore was replaced by specific directions on what to observe, measurements were frequently reported as data or as conclusions, and there was always the "right" answer to the experiment."* (Hurd, 1969). Students need flexibility to stir the imagination. When labs have little flexibility and are based on a set of rigid sequential steps the student becomes mentally passive. There is no need to fully engage the mind. Students only do what is needed, because cookbook experiments do not require creativity. The mind goes into to autopilot and discovery is set aside for the sake of a "correct" result. The traditional process lab is designed as an important bridge between theory and practice, which allows for deeper understanding of abstract ideas, but for true scientific thinking to be birthed the student needs more. *"What the traditional laboratory often fails to capture, however, is the* *process of scientific inquiry – the excitement, intellectual challenge, and, indeed, the frustrations and rewards, that accompany scientific work."*(Green, Elliott, Cummins, 2004). *"Recipe experiments tend to sterilize imagination and initiative, leaving no room for hypothesis, trials, errors, individual responsibility in a group, and above all, preclude the student's involvement in a decision-making process – which is so important to our modern society."* (Gallet, 1998). For the sake of generating true scientific thought and decision-making skills in our students, traditional experiments will not suffice. We must pursue active learning where the whole student is engaged in pedagogical process.

E. Moving away from process labs.

Now the goal lay before us; restructure the laboratory environment into one that fosters higher order pedagogical processing. Leaving traditional verification laboratory experiments that are so deeply entrenched into our classrooms will not be simple. There are many advantages to the traditional lab exercise. Teachers must be convinced of the importance of this change before it will happen in their class. We also need to understand why teachers are hesitant to replace their current laboratory-teaching model for a new one.

In a study of secondary school teachers by Montes and Rockley (2002) found teachers believed there were strong advantages to using traditional verification approach. *"For example, several advantages consistently topping the teachers' list deal with the ease of the verification experiments. Teachers appreciate the fact that they can fit an* *experiment into an allotted amount of time. Teachers also report the verification experiments save time because they are well tested, simple to prepare, easy to grade and are easily adjusted to accommodate small or large classes."* The teacher needs to be able to reach all the learning styles in a classroom as well as meet the rigors of teaching in a secondary environment. Most teachers work within a specific set of guidelines. Their classes are 40-55 minute long, so it is necessary to do experiments that fit into this time frame. Available equipment must be to meet the need of 24-30 students, sometimes in laboratories designed to hold less. The advantages on the benefits of the traditional lab approach seem to hinge more on familiarity and convenience for the teacher. What about the student? Can we change the laboratory setting and meet the needs of both student and teacher? YES!

One approach to achieving change in the laboratory is to rework or modify laboratory exercises that are already being used. Articles have been written discussing how to convert traditional verification experiments into inquiry based experiments. Such as Herman, 1998, Green Elliott and Cummin, 2004 and Clark, Clough and Berg, 2000. This allows the teacher to work within a familiar lab format and provide structure to the student. It also gives the student some leeway to move in the direction of a more pure scientific work. This allows them to generate and test their own hypotheses and draw more independent conclusions. This method allows us to move away from our traditional experiments and begin to embrace the open-ended inquiry approach. It doesn't, however, mean we have to abandon our past. We need to preserve that which is foundationally good in our past practices and build upon them. Allowing ourselves to teach at either extreme is not to the advantage of the student. We need to incorporate that which is good from both view points and work from the fertile ground of learning that comes from balance between these two approaches.

II. The Value of Inquiry Problem-Based Labs.

A. Using higher order Bloom's taxonomy.

The modern student is required to move and work at a faster pace and a much higher level than ever before. Knowledge in many scientific fields is expanding at astounding rates. If our students are to keep up with this increase and continue in the discovery process, it has become necessary for them to work at higher order thinking skills at younger ages. Today students are being required to move beyond the simple lower order cognition skills (LOCS), such as knowledge, comprehension and application to working with higher order cognition skills (HOCS), such as analysis, synthesis and evaluation. A more in depth description of each of these skills is addressed in Table 3, pg. 42. *"The development of higher order cognitive skills in the context not only of the specific content and processes of the science disciplines but also of the interrelationships of science, technology, environment, and society has become one of the most important goals of chemistry and science education."* (Zoller, 1999). To shift from the use of LOCS to the HOCS will require a change in the teaching strategies at all levels of science education, especially at the secondary level in the area of laboratory experiments. Several undergraduate lab manuals were evaluated to assess the claim that traditional labs do little to develop the higher order thinking skills of college students in an article written by Daniel S. Domin (1999). In conclusion he makes the following statement; *"All but one of the laboratory manuals, that foster only lower-order cognition, share a similar structure (i) an introduction in which the concept of interest is presented and explained, (ii) a stepwise procedure, (iii) ready made tables or fill-in the blank sections to record data or results, and (iv) pre-lab and/or post-lab questions that require the utilization of knowledge, comprehension and application."* This is the basic structure of most traditional labs. So where is the student encouraged to do higher-ordered thinking? The traditional laboratory experiments create an environment that is ineffective in fostering conceptual change. These foundational process labs still develop vital skills necessary to perform more in-depth inquiry labs and cannot be thrown out all together. The open-ended lab activity facilitates the development of the higher-order cognitive tasks. These experiments place the student in the position of designing, developing, and conducting their own experiments. This is the essence of inquiry or problem-based learning. The inquiry strategy allows the learner to utilize all six levels of the Bloom's Taxonomy, integrating new experiences with the student's prior knowledge. *"Higher-order thinking skills are recognized as a valuable component of science education and a necessity for young adults entering the work force."* (Domin, 1999) The following table is a quick reference to the six cognitive levels identified by Bloom. A brief description and illustrative phrase is included with each level.

Table 3: Descriptions and Illustrative Phrases of the Six Major Categories of Bloom's Taxonomy of Educational Objectives

Cognitive Skill	Description	Illustrative Phrase
Knowledge	The remembering of previously learned material.	Defined terms, identifies objects, states steps in a procedure.
Comprehension	The ability to grasp the meaning of the material.	Explains the concept, interprets the graph, generalizes the data.
Application	The ability to use learned material in new and concrete situations.	Solves problems, utilizes concept in novel situations, constructs graphs.
Analysis	The ability to breakdown material into its component parts.	Identifies pertinent data, identifies inconsistencies, establishes relationships between items.
Synthesis	The ability to put the parts together to form a new whole.	Formulates an hypothesis, proposes a plan for experiment, proposes alternatives.
Evaluation	The ability to judge the value of the material based on the definite criteria.	Judges the value of data, judges the value of experimental results, justifies conclusion.

(Gronlund, 1985)

It is only when the lab experiments are designed to push the students to analyze, synthesize and evaluate will we begin to foster greater student learning.

B. Investigative experiments enhance student learning.

Traditionally, scripted lab activities are extremely effective in developing a student's observational skills, lab-measuring skills and conveying the importance of precision and accuracy in chemical measurement. They allow for an essential connection to be formed between theory and practice so deeper understanding of abstract concepts can occur. Where is the investigative thinking, the scientific processing? Are the students becoming scientists? Are they answering questions, solving a problem they encountered? True learning involves these types of processes. *"Inquiry-based learning, by contrast, emphasizes the explicit use of the scientific method and invites students to generate and test their own hypotheses."* (Green, Elloitt, Cummins, 2004). In efforts to revitalize secondary chemistry courses and make the learning more relevant, teachers are revising their methodologies and are using the inquiry problem-based approach more widely in their classrooms.

There is a broad consensus that science education needs to engage students as active learners. (NSTA, 1987). This focus can be seen throughout science from new textbook designs to catalogs selling project based lab activities. Investigative learning is even making it into larger science conferences in education. This is because open-ended laboratory activates require more of the student to get involved. Inquiry emphasizes the use of the scientific method and invites students to generate and test their own hypotheses. The student is given the chance to have more ownership in the laboratory work and enjoy the opportunity to actually practice science as a real scientist might. This type of lab work is more closely related to real-life. Leonard (2000) points out that more significant active learning takes place in laboratories that model real-life applications and allow the student to construct their own investigations. If we want to reach a vast number of students in our society and create a larger pool of scientific candidates to replace our science community we need to be engaging more students in scientific thought at the secondary level. Inquiry science is improving learning by inviting more students to focus in on science and develop deeper understanding.

C. Students must participate in the pedagogical process.

Effective science is one where the students take an active role in the learning process. Shavelson, Baxter and Pine (1991) point out the research done by Glaser (1984) and Resnick (1987) on cognition and instruction has changed our notions on how instruction might be designed to facilitate learning.

> *"Rather than arranging instruction in a series of small steps that move students from basic skills and facts to concepts and from concepts to problem solving, a more holistic approach is taken. Students are viewed as active agents in the teaching-learning process, constructing personal and shared meaning in the subject matter. ...Hands-on activities and long term projects are the rule rather than the exception."* (Montes and Rockley, 2002)

This coincides with other researchers that agree for students to master knowledge, a student "*must participate in the pedagogical process... instead of being a passive receiver.*" (Whitehead, 1929). *"Inquiry investigations encourage students to actively participate more in science, even more notable in females."* (Russell and French 2002). Students need to buy-in to the learning process, allowing them to think, ask questions and evaluate, not just memorize. We need to bridge those gaps that we created from teaching chemistry through simple cookbook style labs. We need to make the lab more relevant, interesting and applicable to real-life. We have to revitalize the laboratory setting and push students into a place that minimizes the chance for complacency and passivity. *"Research shows students learn best when they can build on past experiences, construct their own knowledge in collaboration with other students and faculty and communicate their results effectively."* (Lundsford, Strope, 2002)

D. Inquiry takes longer and requires more effort.

All change brings new challenges. Inquiry-based teaching is not without it difficulties. These hurdles can be broken down into to three major areas: teacher preparation, materials and the most important of all, time. The adoption of inquiry-based experiments into the majority of high school programs is happening at a much slower pace than the amount of inquiry teaching materials being produced. Why are teachers reacting slowly to this sweeping change in laboratory instruction? The focus of the 2004 Michigan Science Teachers Convention was "Science through Inquiry". Educators want it, reformers encourage it and students need it, so why is there a lapse in the movement from theory to practice? There are advantages in the traditional verification experiments and disadvantages in the inquiry-problem base approach that need to be addressed.

Convenience is of great importance to the secondary educator. Many teachers have been brought up in traditional style of teaching and learning. These traditional labs were simple, cookbook style, process labs that were easy to conduct. It was the way they were taught and the way they learned how to process information scientifically. We teach what we know. *"While the decision to provide students with practical laboratory experience is based on pedagogical reasons, the decision about what approach to use is often made for the reason of familiarity or convenience."* (Montes and Rockley, 2002). Traditional verification lab manuals are still widely available and commonly used in most secondary settings. These experiments are strongly entrenched in secondary curriculum because they fit the school structure. A close relationship between a particular experiment and lecture is an advantage of the traditional lab. An appropriate experiment can be chosen that complements the lecture. Some inquiry labs may require more knowledge or skills that have not been yet taught in the course. Teachers are going to need better preparation on how to align and implement appropriate inquiry problem-based experiments into their current curriculum.

"This (Inquiry) *manner of instruction, although possessing the potential to foster all orders of cognition and meaningful learning, resurrects the problems that traditional labs have resolved so effectively: the management of resources."* (Domin 1999) Designing an experiment involves a considerable amount of time. Unique designs may require too much or too costly equipment. These are two of the major concerns at the secondary level: time and money. In my experience with inquiry I have also noticed this need for students to process, develop and test hypotheses. However, what would usually take about seven weeks for my students to complete in material was now taking ten to eleven weeks. There is a significant time requirement to complete inquiry science. Curriculums would have to be adjusted to allow this inquiry approach, but the overall advantage in student development is worth it.

E. When is enough enough?

Science education is swarming with many new and old pedagogical ideas. Educators are constantly trying to improve their instructional approach and technique. The push to change and improve surrounds us constantly. Meaningful learning is the expectation set before us. Each new idea has it costs and inquiry based teaching is not without it challenges. *"Designing an experiment requires a considerable amount of time,* *making it impossible to cover the same amount of content in the allotted time. Different students may design experiments that require different pieces of equipment, creating a logistical headache for the laboratory preparation."* (Domin, 1999). How much time do we have? Time is always of a premium and not without its constraints. Content must be provided and topics must be covered. As in the marriage of all good ideas, there needs to be some give and take. Numerous articles alluded to the fact that the open-ended, problem based laboratory approach does take considerable time to be done appropriately. (Green, Elliott and Cummins, 2004) and (Monte and Rockley, 2002) Even in my own experiences of trying to incorporate more inquiry experiments, weeks needed to be added to cover the same amount of material. Is the reward enough to keep us moving in this direction? We have to for the sake of developing strong scientific minds.

III. Bridging the Gap between Cookbook Labs and Investigative Labs.

A. Is there enough background to build upon?

Schools are designed on the concept of prior knowledge. The activities determined for the second grade is based upon what is taught in the first grade. This process is supposedly done through all twelve grades. Entire school systems are gathering their educators from kindergarten through high school to align their curriculums in every area from Science to Music. Each year chemistry teachers began their course with some expectation that students possess a particular set of lab skills. Chemistry textbooks are being produced with reviews that continually test prior concepts as new material is presented. All meaningful learning comes from the learner hinging their new knowledge upon cognitive mindsets of the past.

> *"In order for meaningful learning to take place, three conditions must be satisfied; (i) a student must have relevant prior knowledge to which the new information can be related in a non-arbitrary manner, (ii) the material to learn must be meaningful in and of itself; that is, it must contain important concepts and propositions relatable to existing knowledge, and (iii) a student must consciously chose to non-arbitrarily incorporate this meaningful material into his/her existing knowledge, a disposition which Ausubel labels as the meaningful learning set.* (Ausubel, 1963)

Relevant prior knowledge must be built into the foundations of our secondary students if they are to be successful with open-ended inquiries. Even with this work on the part of educators to build strong foundational knowledge, each student waltzes into our room lacking important laboratory skills. Greater emphasis must be made to determine what our students 'do' know and what they 'need' to know to be more successful. This can be achieved through modifying existing traditional experiments to encourage and develop necessary lab skills while enhancing the learning environment with higher order thinking skills. "*Effective science teachers creatively modify activities to incorporate students' prior knowledge, engender active mental struggling with prior knowledge and new experiences, and encourage metacognition.*" (Hand and Keys, 1999). Then new inquiry labs can be introduced to help the student master scientific reasoning.

B. More work getting in, but learning is higher.

Although the inquiry-based science seems to be the new educational thrust these days, many materials are still available based on traditional methods of instruction and lots of teachers are still quite content using them. What will be the deciding factor to prompt educators to embrace this new type of instruction? Effective teachers will always be open to new forms of instruction as they begin to understand their benefits. *"As teachers gain familiarity with inquiry experiments and the availability of the experiments increases, teachers will be more comfortable choosing this laboratory approach that has advantages based on both pedagogy and convenience.* (Montes and Rockley, 2002) Teachers are discovering that the laboratory can be a richer learning environment for students. A place where students can learn what it really means to do science. There are some obstacles to overcome if a complete transformation is to take place within the laboratory environment. Time, money and teacher confidence are the largest opponents to this sweeping change in laboratory science. If done in smaller pieces each teacher can adapt their laboratory course to reach their full potential. *"Introducing project-oriented format increases the preparation time for reagents and materials and requires vigilant safety rule enforcement. These major practical issues suggest most colleges and universities will be more successful at changing the laboratory in increments rather than introducing sweeping changes in the lab curriculum."* (Herman, 1998) Implementing improvements is never without its struggles and growth always has it costs. As educators we need realize verification experiments do not allow students to fully develop their problems solving skills, so we are forced in to changing our methodology. Our decisions about which lab approach to use cannot always be made by reasons of familiarity and convenience. As we examine the gains and loses from each type of laboratory activity and discover the lab can be transformed in to a richer learning environment, we will be more eager to implement the inquiry approach to science. Creating a discovery lab setting may require more commitment and time, but as we assess our overall goals of the science lab we soon realize that the learning in an inquiry atmosphere will be much higher.

C. Balance is better

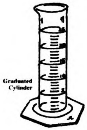
Inquiry laboratory activities have taken the secondary high school lab to a higher place of learning. Students are more involved on the pedagogical process and are being allowed the time for deep processing. *"It is through deep processing that students are able to integrate new experiences with prior knowledge, establish a context for the purpose of the laboratory activity, and determine it relevance to themselves—all of which are characteristics of meaningful learning."* (Novak and Gowin, 1984). Traditional laboratory activities, which sometimes seem simplistic with their recipe approach, are also at the heart of this learning. These activities expose each student to new and important skills, which are vital to making powerful hypotheses and establishing strong conclusions No single method will suffice if our students are to become the scientists our society will require tomorrow. The job market is demanding a work force that possesses greater hands-on experimentation, problem solving and critical thinking skills. Traditional labs coupled with inquiry experiments are helping our students meet this calling. *"In rethinking laboratory activities, teachers too often are presented with a false dichotomy: at one extreme, students passively follow a cookbook laboratory procedure* *or, at the other extreme, investigate a question of their own choosing. These extremes miss the large and fertile middle ground that is typically more pedagogically sound than either end of the continuum."* (Lazarowitz and Tamir, 1994) We also have to understand how these changes will impact the educators. Teachers are constantly being given new tasks and agendas. Time is of a premium and not all changes can be logically placed within the existing classroom framework. There is significant time involved and this change will require new mindsets. Replacing traditional process labs with investigative inquiry-based labs needs to be done at a pace that is comfortable to the teacher. As these new methods are introduced and brought alongside the quality process labs we are already conducting a balance will soon begin to emerge. This is a balance which will move students to deeper levels of thinking and higher level of achievement within science. *"If one lab per semester or year is adapted to an investigative format, a balance eventually can be reached between open-ended laboratory experience and more traditional opportunities to practice complex experimental techniques."* (Herman, 1998). We need to see the definite advantages of both pedagogically sound instructional methods and incorporate them into the curriculum to improve our overall result; highly qualified scientific thinkers.

Appendices

Pre-test

Name ______________

1) Name the following pieces of equipment.



A)__________

B)__________

2) What would you use a graduated cylinder for and for what kinds of materials?

3) Draw a picture of a setup you would need to boil water in a science lab.
Label each part of your drawing.

4) Write a brief summary of the steps a scientist would go through when they are trying to solve a problem.

5) Three unmixable liquids were poured into the same container, which of the following will float on the top? Explain why your choice.

   A. 0.76 g/ml
   B. 0.99 g/ml
   C. 0.75 g/ml
   D. None

6) How would you find the density of an unknown material and what would be useful about this information?

7) A scientist runs an experiment and comes up with the following density results

$0.66\ g/cm^3$
$0.64\ g/cm^3$
$0.69\ g/cm^3$

The actual density is $0.65\ g/cm^3$. From this data would say this is a reliable lab and should he trust the results? Explain or defend your answer.

8) Two solids, barium hydroxide and ammonium nitrate are mixed together. As the reaction proceeds it becomes extremely cold, so cold that if it is placed on wet board it will freeze to the board. Explain what is happening.

9) A package label says there are 100 Calories in each serving. What does the calorie amount tell you about the food and why is this information important to the consumer?

10) Someone gives you a sealed box with an object inside and asks you to tell them what is inside the box without ever opening it. You can do any test you want. However, you realize x-rays cannot penetrate the box so you will never see the object, but you still need to come up with a solution. How confident would you feel about your solution if you could never see inside?

"1" means, <u>not confident at all</u> and
"5" means, <u>I would be positve.</u>

1 2 3 4 5

They then tell you, they have never seen the object either. They say they are positive and they know what the object is. How confident would you feel about their answer?

1 2 3 4 5

You can clarify your choice with some remarks if you choose. Please be brief.

Pre-test Scoring Rubric

1) Name the following pieces of equipment. **4pts total**

A) **<u>Graduated Cylinder</u>** B) **<u>Beaker</u>**

2pts **2pts**

2) What would you use a graduated cylinder for and for what kinds of materials? **3pts total**

To measure the volumes of liquids or solids by displacement.
1pt 1pt 1pt Optional (1pt)

3) Draw a picture of a setup you would need to boil water in a science lab. Label each part of your drawing. **4pts total**

Container (Beaker)	**1pt**
Support (Ring Stand, Iron Ring, Gauze)	**2pts**
Heat Supply	**1pt**

4) Write a brief summary of the steps a scientist would go through when they are trying to solve a problem. **4pts total**

State the problem	**1pt**
Form a hypothesis	**1pt**
Conduct experiments	**1pt**
Form a conclusion or theory	**1pt**

5) Three unmixable liquids were poured into the same container, which of the following will float on the top? Explain why your choice. **4pts total**

A. 0.76 g/ml Middle
B. 0.99 g/ml Bottom
C. 0.75 g/ml Top Lowest density will rise to the top.
D. None

2pts 2pts

6) How would you find the density of an unknown material and what would be useful about this information? **4pts total**

Density = mass/volume 2pts

Uses: identification of materials, ability to sink or float in water. 2pts

7) A scientist runs an experiment and comes up with the following density results

0.66 g/cm^3
0.64 g/cm^3
0.69 g/cm^3

The actual density is 0.65 g/cm^3. From this data would say this is a reliable lab and should he trust the results? Explain or defend your answer. **3pts total**

Reliable (Acceptable); Every experiment is susceptible to error and multiple trials are required to validate results 2pts
1pt

8) Two solids, barium hydroxide and ammonium nitrate are mixed together. As the reaction proceeds it becomes extremely cold, so cold that if it is placed on wet board it will freeze to the board. Explain what is happening. **4pts total**

A Chemical reaction is taking place where heat is being absorbed. Endothermic.

2pts

So much heat is absorbed that the water freezes causing the container to bond to the board. 2pts

9) A package label says there are 100 Calories in each serving. What does the calorie amount tell you about the food and why is this information important to the consumer?

2pts A calorie indicates the amount of energy required to break a substance down.

2pts This tells the consumer how much energy will have to be expended to digest or breakdown this food.

10) Someone gives you a sealed box with an object inside and asks you to tell them what is inside the box without ever opening it. You can do any test you want. However, you realize x-rays cannot penetrate the box so you will never see the object, but you still need to come up with a solution. How confident would you feel about your solution if you could never see inside?

"1" means, <u>not confident at all</u> and
"5" means, <u>I would be positve.</u>

1 2 3 4 5

They then tell you, they have never seen the object either. They say they are positive and they know what the object is. How confident would you feel about their answer?

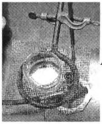
1 2 3 4 5

You can clarify your choice with some remarks if you choose. Please be brief.

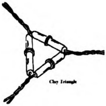
Survey

Post-test Name ______________

1) Name the following pieces of equipment.



A)___________



B)_____________

2) For what reason(s) would you use a watch glass in an experiment?

3) You want to find the calories of a new food source. Draw a picture of the set-up you would need to do this experiment. Label each part of your drawing.

4) A large number of deer were found dead by a DNR officer. A set of scientists were sent to investigate. There were veterinarians, doctors, biologists and chemists. Write a brief summary of the steps you think they would take to solve this problem.

5) Given the density of three solids and knowing the density of water is 1.00 g/ml. Which of the following will sink and which will float in the water? Explain why your choices.
   a. 7.76 g/ml
   b. 0.98g/ml
   c. 1.02 g/ml
   d. All will sink

6) A person tells you they have found some gold and they want you to tell them if it is really gold. How could you experimentally prove to them if it is gold or not from the methods we learned in this unit.

7) A researcher discovers a cure for cancer, but the problem is he did the experiment only once on a lab rat. His work is well documented and seems very credible. He wants to get it marketed right away. From this information would you say this is a reliable lab and should the results be trusted? Explain or defend your answer.

8) A person tells you that since it takes energy (a match) to start a fire it is actually an endothermic process. Is this person correct? Explain

9) One package label says there are 1,000 Calories in each serving, but there is only one gram of fat. Another package says there is 1,000 grams of fat and only one calorie. What does this tell you about each of the foods and why is this information important to the consumer?

10) Someone gives you a problem to solve and you can get help from anyone or anywhere you want. You have a lot of time to work on a solution, but it has never been attempted. Do you feel you could come up with a method(s) to attempt to solve this problem or at least conduct a scientific approach and answer some questions?

"1" means, not confident at all and
"5" means, I would be positive.

1 2 3 4 5

You can clarify your choice with some remarks if you chose. Please be brief.

Post-test Scoring Rubric

1) Name the following pieces of equipment. **4pts**

A) **<u>Iron Ring</u>** B) **<u>(Clay) Triangle</u>**

2pts **2pts**

2) For what reason(s) would you use a Iron Ring in an experiment? **3pts**

For supporting equipment, hold objects above burners or stabilize equipment
2pts 1pt or 1pt

3) You want to find the calories of a new food source. Draw a picture of the set-up you would need to do this experiment. Label each part of your drawing.

4pts total

Most students will draw the equipment used in the lab; "Calorie Determination of an Unknown Food"

Support (Ring stand and ring)	**2pts**
Pop can and Tin Foil Heat Shield	**1pt**
Thermometer	**1pt**

4) A large number of deer were found dead by a DNR officer. A set of scientists were sent to investigate. There were veterinarians, doctors, biologists and chemists. Write a brief summary of the steps you think they would take to solve this problem. **4pts total**

Gather Data,	**Hypothesis**	**1pt**
Conduct Autopsies,	**Experiment**	**1pt**
Test the area for contaminants,		**1pt**
Make a conclusion		**1pt**

They would use the scientific process based on their specific science 4pts
(Hypothesis, Gather Data, Experiment, Make conclusions)

5) Given the density of three solids and knowing the density of water is 1.00 g/ml. Which of the following will sink and which will float in the water? Explain why your choices.
   a. 7.76 g/ml
   b. 0.98g/ml
   c. 1.02 g/ml
   d. All will sink

   (A & C) will sink, densities are greater that water (1pt, 1pt)
   (B) will float, density is less than water. (1pt, 1pt)

6) A person tells you they have found some gold and they want you to tell them if it is really gold. How could you experimentally prove to them if it is gold or not from the methods we learned in this unit. **4pts**

   Determine it density and compare it to the true density of gold. 2pts

   Find the sample's mass and volume then divide (mass/volume) 2pts

7) A researcher discovers a cure for cancer, but the problem is he did the experiment only once on a lab rat. His work is well documented and seems very credible. He wants to get it marketed right away. From this information would you say this is a reliable lab and should the results be trusted? Explain or defend your answer.

   1pt 1pt
   Not reliable. The lab needs to run numerous times to prove its validity,

   because there is error in all experimentation, There should also be

   some human testing. 1pt

   3pts total

8) A person tells you that since it takes energy (a match) to start a fire, it is actually an endothermic process. Is this person correct? Explain. **4pts**

No.	**1pt**
This starting energy is called the activation energy and	**2pts**
the burning of wood is an exothermic process.	**1pt**

9) One package label says there are 1,000 Calories in each serving, but there is only one gram of fat. Another package says there is 1,000 grams of fat and only one calorie. What does this tell you about each of the foods and why is this information important to the consumer?

The first food has a lot of calories, but they are not mainly form fats. **2pts**

The second food has fat but it does not contribute to the calories count. **2pts**

10) Someone gives you a problem to solve and you can get help from anyone or anywhere you want. You have a lot of time to work on a solution, but it has never been attempted. Do you feel you could come up with a method(s) to attempt to solve this problem or at least conduct a scientific approach and answer some questions?

"1" means, <u>not confident at all</u> and
"5" means, <u>I would be positive.</u>

1 2 3 4 5

You can clarify your choice with some remarks if you chose. Please be brief.

Open ended survey question for comparison

Retention Test   Name ____________

1) List the pieces of equipment you would need to determine the density of an unknown metal sample.

2) What would be the mass of a 250 mL sample if the density of oil is 0.92 g/mL? Show your work!

3) How is light created?

4) If you were to monitor the temperature of an endothermic reaction, how would the temperature change over time?

5) Why do scientists run multiple tests before they accept or publish any results?

Retention Test Scoring Rubric

1) List the pieces of equipment you would need to determine the density of an unknown metal sample. **4pts total**

Equipment	**Graduated Cylinder**	**2pts**	
	Balance	**2pts**	
	Beaker/ Water	**1pt**	**(optional)**

2) What would be the mass of a 250 mL sample if the density of oil is 0.92 g/mL? Show your work! **4pts total**

D = M/V	**so**	**M = D x V**	**2pts**
		M = (0.92g/ml) x (250mL)	**1pt**
		M = 230 g	**1pt**

3) How is light created? **4pts total**

Light is created by electrons moving from higher energy level (states) to lower
2pts **2pts**

levels and release energy in the form of light.

4) If you were to monitor the temperature of an endothermic reaction, how would the temperature change over time? **4pts total**

Endothermic reactions absorb heat and lower the temperature of objects they touch. **1pt**

The temperature would decrease. 3pts

5) Why do scientists run multiple tests before they accept or publish any results? **4pts total**

To improve Accuracy and Precision, Remove errors and create validity.
2pts or 2pts or 2pts

What is it for? Chemical Equipment

Pre lab discussion

Most experiments require the investigator to make some quantitative observations, or measurements. The numerical values of these measurements are called data. The most frequently measured quantities in the chemistry laboratory are mass, volume, and temperature.

When conducting an experiment of a quantitative nature, the first step in the procedure is to make and record measurements of the materials that are being investigated. If the materials take part in a chemical reaction (undergo chemical change), many, if not all, of the initial measured values probably will change. The nature and extent of these changes often help the investigator to understand what is taking place. Some of these changes, such as temperature change, can be measured and recorded as the reaction is taking place. When the reaction is ended, measurements again are made and recorded. The collected data from all these measurements provide an overall record of what quantitative changes took place during the reaction.

When making measurements, you should keep in mind that the numerical values can be only as accurate as the instruments used to make the measurements. These values also are affected by the care and skill of the person using the instruments. As a scientist you need to make accurate measurements, this requires extending the precision of the instrument being used. As you gain more experience in the laboratory, you will become more familiar with the limitations and accuracy of the various instruments you use. You also will become more skillful in the use of these instruments and in carrying out various activities that are essential to a successful investigation.

Scientists must be imaginative. In many cases, they must devise their own experiments and decide what measurements will provide useful information. In this investigation, you will make measurements to determine the effects of a chemical reaction (combustion). You will then be asked to decide how these measurements can be used to extend your understanding of the reaction.

Prelab Questions

1) What is the numerical information in lab called?
2) What are some changes that indicate a chemical reaction may have taken place?
3) Why do we approximate another decimal place when we measure with certain instruments?

Purpose

Make a quantitative investigation of a chemical reaction.

Equipment

Laboratory balance
Ring stand
Iron ring
Wire gauze
Thermometer
Graduated cylinder, 100 ml
Stop watch
Index card
Safety goggles
Lab apron
Candle
Matches
250 ml beaker

Safety

In this experiment, you will be working with an open flame. Tie back long hair and secure loose clothing. Also, wear safety goggles and a lab apron at all times when working in the lab. Be sure matches are completely extinguished before they are discarded.

Procedure

1. Find the mass of the candle. Use the same balance for the entire lab. Each balance will be slightly different than another. This can cause error.
2. Measure (50mL to 100mL) tap water in a graduated cylinder. Record the exact amount in your chart. Pour the water into a 250 ml beaker and place the beaker on the wire gauze. Measure the temperature of the water.

See figure 2-1 for equipment set-up located in Lab book on page 8.

Caution! Do not let the beaker fall or let the candle melt onto the ring stand!

3. Light the candle and place it on the index card. Adjust the height of the ring so that the flame is 2 cm below the base of the beaker. Using the candle, heat the water for exactly 4 minutes. Extinguish the flame and measure the temperature of the water and the mass of the candle.
4. Relight the candle and repeat steps 1 – 3 for the second trial.

Data Sheet: Lab #1 Equipment

Names: ____________________

____

Observations and Data ***Show correct decimal places**	**Trial 1**	**Trial 2**
Original mass of candle	_ _ _. _ _ _	_ _ _. _ _ _
Mass of candle after burning	_ _ _. _ _ _	_ _ _. _ _ _
Time candle burned	_ _ _. _ _ _	_ _ _. _ _ _
Original temperature of water	_ _ _. _ _ _	_ _ _. _ _ _
Final temperature of water	_ _ _. _ _ _	_ _ _. _ _ _

Calculations:	**Trial 1**	**Trial 2**
1. Change in the mass of the candle **Work:**	_______	_______
2. Change in the mass of the candle per minute. **Work:**	_______	_______
3. Change in temperature of the water **Work:**	_______	_______
4. Change in temperature of the water per minute **Work:**	_______	_______

Conclusions and Questions

1. Comparing your trial results and calculations.
   Are your results exactly the same? If one set of data differs from another in an experiment, does this mean that one or both sets are wrong? Explain your answer.

2. Why do scientists trust their experiments when the results are never exactly the same? What does running multiple trials do for their results?

3. Explain how the heat from the combustion reaction is related to the temperature change of the water?

4) How does the precision of a scientific instruments effect our results? Discuss.

How does it work? Scientific Process.

Discussion

Every scientist has been born through curiosity. The true scientist has always had the desire to know why something happens, but they are willing to be systematic in their approach. They are willing to take slow detailed observations. As a new and upcoming chemist you need to be organized in how you approach scientific experimentation. Many students take chemistry to satisfy a requirement and never really understand how to be a scientist. They would rather read a book, listen to a couple lectures then take a test and leave. The scope of this course is to teach you how to be problem solver and come up with answers to problems.

The scientific method has generally four parts. First, a question to be answered. Second, a hypothesis or a guess of what is happening. Third, an experiment to prove or check the guess. Finally, a conclusion stating a scientific truth proven from the investigation. In this lab we are going to ask you a question. Your job will be to run a series of experiments and formulate a final conclusion from what you learned.

Purpose

Answer the question what happens to the melting and boiling point of water when different materials are dissolved in it using the scientific process.

Pre-lab questions

1) How is a scientist different for a science student?
2) What is the four part of the scientific process?
3) Give an example of how you solve problems in your everyday life?
   What do you do if the first attempt doesn't fix the problem?

Inquiry Question

Does the melting and boiling of water change when substances are dissolved in it and is the material important?

Hypothesis (Write out your thoughts to the following questions before you start the lab)

What do you think will happen to the ice when salt is added? The temperature?
What do you think will happen to boiling water when salt is added? The temp?

Procedure (Experimenting)

Part A

1) Measure out 10 grams of salt and 10 grams of sugar on separates sheets of weighing paper.
2) In three beakers put 100ml of ice.
3) Add the sugar and salt to two of the beakers and nothing to the third. The one without anything will be your standard.
4) Set-up a data sheet and record everything you observe visually about the beakers every 2 minutes for 20 minutes.
5) Using a thermometer take the temperature of each beaker ever two minutes and record this along with your other observations.

Part B

1) Measure out 10 grams of salt and sugar on separate sheet of weighing paper.
2) Add 100 ml of distilled water to three beakers.
3) Add the salt and sugar to separate beakers and dissolve.
4) Bring the plain water to boil using your ring stand and burner. Record the temperature of the boiling water and recheck every minute for 5 minutes. Notes any changes in the temperature. This will be your standard.
5) Boil the other two solutions. Allow them to boil for 5 minutes while you record the temperature every minute. Use the same thermometer for each trial!

Analysis (Making conclusions)

After a scientist has completed their lab work they must decide what they have found and try to draw some logic from the data. The following questions will help you to make this transition.

1) What was the purpose of the lab?
    a. In this lab we were trying to ...

2) What did your data reveal?
    a. From our results we found ...

3) What truth can you state about what you learned based on the purpose of the lab?
    a. The melting and boiling of water will ... when ... is added.

Try to answer the following questions in your conclusion. Your score will be based on these being answered in your final report.
Did the salt or sugar have any effect on the ice? Did the salt or sugar have an effect on the boiling point of the water? Did one have a greater effect than the other? What did you learn that you did know before?

Density

Pre-lab Discussion

An old riddle asks, "Which is heavier, a pound of feathers or a pound of lead?" The question in nonsensical, of course, since a pound of feathers and a pound of lead weigh the same, one pound. Nevertheless, there is clearly something different about a small lead brick and a large bag of feathers, even though they weigh the same. The key to answering the riddle is understanding the relationship that exists between a substances's mass and the volume it occupies. This is also why the same mass of two different materials will not have the same volume.

Chemistry is the study of matter, which usually is defined as anything that has mass and volume. You already have some experience determining mass in the laboratory. In this experiment, you will measure volumes of different materials, using direct and indirect methods. You will also us the relationship between mass and volume to determine the density. *Density* is defined as the ratio of a substance's mass to the volume it occupies.

$$\textbf{Density} = \frac{\textbf{mass of substance (g)}}{\textbf{volume of substance (ml)}}$$

Many solids do not lend themselves to direct measurement of their dimensions. These include irregularly shaped objects, such as rocks and very small objects. Volumes of such solids can be measured by water displacement very accurately. If a solid is immersed in a liquid, such as water, it will displace, or raise the level of the liquid, a volume of water that is equal to its own volume.

You are expected to use the measuring skills you developed in earlier labs to determine the mass and volume of specific materials. You will then be required to calculate the density of these substances with the data you collected. One final question we will try to answer is density an external or internal property.

Pre-lab questions

1) How do you calculate density?
2) What is the method for finding the volume of strangely shaped objects.
3) What is the difference between an extensive and intensive property.

Purpose

Be able to determine the identity of a substance by finding it's density in a lab and conclude if density is an extensive or intensive property.

Materials

Triple beam lab balance
50 ml beaker
metal sample
graduated cylinder, 10ml and 50ml
distilled water
safety goggles and apron

Procedure

Caution: Not being exact on your measurements will cause greater variances in your density calculations and this will make it harder to identify the metal.
Spend time making careful measurements!!!

Water

1) Weigh a clean dry 50 ml graduated cylinder.
2) Add some distilled water to the container (10-20 ml) and record the exact volume.
3) Weigh the cylinder and the water together. Record this weight.
4) Add more distilled water to the cylinder so that the level is between 25-35 ml. Record the exact volume and weight of the cylinder again.
5) Add more water so that you have three volumes of water and their three corresponding weights. Make sure all your data is recorded in the table.

Metal sample (use tap water)

1) Add 25 ml of tap water to a 50 ml graduated cylinder. Record the exact volume.
2) Weigh a clean dry empty 50 ml beaker.
3) Add 50 metal pellets to the beaker and weigh again.
4) Carefully add the pellets to the graduated cylinder with the water and record the new water level.
5) Add 50 more pellets to the beaker and weigh again. Add this weight to the first 50 pellets mass and record it as the mass of 100 pellets on the following table.
6) Add them to the cylinder and record the new water level.
7) A Weigh out 50 more pellets and repeat the steps above, so that you have three separate amounts of pellets and three separate volumes.

Data Table

Weight of graduated cylinder ____________ (g)

Material	Mass Cyl. + Water (g)	Mass Water (g)	Volume (ml)
Water (Vol. #1)	_________	_________	_________
Water (Vol. #2)	_________	_________	_________
Water (Vol. #3)	_________	_________	_________

Weight of beaker ______________ (g)

Material (ml)	Mass (g)	Initial water level (ml)	Final water level (ml)	Volume
Metal (50)	_________ _________	_________	_________	
Metal (100)	_________ _________	_________	_________	
Metal (150)	_________ _________	_________	_________	

Calculations: Show your work for full credit!

Density of water

1) ________________ 2) ________________ 3) ________________

Average density ______________

Density of metal

1) ________________ 2) ________________ 3) ________________

Average density ______________

Names:__________________

____

Analysis
Use the following information to decide what your unknown metal is.

Lead	11.34 g/cm^3		
Copper	8.93 g/cm^3	Unknown Metal	______________
Aluminum	2.70 g/cm^3		
Water	1.00 g/cm^3		

1) Using the above values determine the % error of your lab data.

Work

$$\% \text{ Error} = \frac{\underset{\text{(Chart)}}{\text{True Value}} - \underset{\text{(Avg. Density)}}{\text{Experimental Value}}}{\text{True Value}} \times 100$$

Water:

Metal:

2) During the experiment you were constantly changing the mass and volume of each sample, but now you want to look at the values of the density. Did they change? Based on this finding can you conclude whether density is an extensive or intensive property? Explain you reasoning.

3) What could be possible sources of error that allowed your values to slightly different from each other and the accepted value? Is human error acceptable in scientific experimentation? What things could you control and not control?

4) Write a conclusion for this lab on the back of this sheet.

Rich Chemical Corporation

To: Chemistry Division
From: Field Geologist
Re: Unknown Samples

Lab Chemist,

We have just recently explored a tract of land the company acquired. We are sending you some samples. Please identify these materials. We are excited about the possibility of opening a new mining operation. We believe we have located a large source of potential profits. We would like a report showing all your lab work.

This should include:
Equipment you used,
Procedure,
Data,
Calculations
and final results.

We are also interested in the current market value of each material. Please include this information in your summary, along with your opinion which material we should focus on in our attempts to make this venture profitable. We are very eager to hear back from you. Thanks.

Jim Digger
Field Geologist
Rich Chemical Corporation

Endothermic or Exothermic?

Demonstration **Name** ___________________

Equipment: A Re-Heater reusable heat pack and an Athletic Disposable ice pack.

Pre-Demo Question

1. Give an example of an endothermic process.

2. How does an exothermic process feel?

Activate and handout hot and cold packs to students.

Post-Demo questions

3. Give and example of an exothermic process.

4. What happens to the temperature of and endothermic process as it proceeds?

5. Give some practical uses of endothermic and exothermic reactions.
Think outside of the demonstration.

Tasty Foods Incorporated

To: Food Analysis Division
From: Quality Control
Re: Product Calorie Identification

Lab Chemist,

We are currently ready to market a new enhanced food product we have produced in our labs. To make them marketable we need to identify the amount of calories in each. Please run a survey of some common food products. Run a comparison of our product alongside of them.

This should include:
Equipment you used, (Drawing)
Procedure,
Data,
Calculations
and final results.

Please suggest a serving size based on the number of calories you found. Let us know the amount of error in your process. We will need to know this when we make our final decision. Please give a brief discussion on your opinion of the taste of our product. We would like any comments or suggestions included with your report. Such as where and how we should display the product in the store. Health, snack dairy section, etc.

Sarah Sweet
Food Development
Tasty Foods Inc.

Copyrighted Lab References

"Heat of Fusion of Ice Lab" Reference:

Wagner, M. (1987). Calorimetry: Heat of Fusion of Ice. Prentice Hall, Chemistry; The Study of Matter,, Laboratory Manual, 4th Edition, Lab #7 , 37-42.

Ob-scertainer Lab Reference:

OB-SCERTAINER™ KIT, Catalog No#. 100. Lab-Aids Inc. 17 Colt Court, Ronkonkoma, New York 11779.

Mystery Box Lab

Discussion:
The first scientists were very limited in the equipment that is available to modern scientists. We know have cyclotrons, x-ray, gas chromatograph, sonar, electron microscope and not to even mention the numerous technology available in every laboratory around the world and found in our homes. They had to depend on simple ideas of logic and deduction. Today's scientists are still proving what others did hundreds of years ago to be true. How did they get such good results and why were they willing to trust what they did? This is what every scientist must decide. When do I trust my results? We are going to give you the chance to believe in your work and stand on your results

Purpose:
To understand how scientists used observations to discover chemistry ideas without the aide of modern science and technology. Then decide on a theory based on your observations without ever seeing the answer. "Believing without seeing."

Pre-lab questions:

1) Why do you believe scientists were willing to accept the results of their experiments? The same can be asked to us why do we think our experiments are trustworthy?
2) How often do you have to make decisions without having all the information? Give an example.

Procedure:
Rotate or tip the mystery box and listen for the sounds of the washers inside the box. They can be anywhere. (Loose or on the sticks) From the experiments you conduct we want you to come up with a description of where you believe the washers are located in the box. Draw a picture of the set up inside the box.

Simple observations:

1) Keep the letter "F" in the front right hand corner to be consistent.
2) Tilt the box front to back and **listen carefully**. You may be able to feel the washer's movements. Record all observations.
3) Then tilt the box from side to side and record your observations.
4) Then make a hypothesis of box layout inside.

Complex observations:

1) Predict what you believe will happen when you pull out a stick. You can start with
any stick you want. Just be sure to record, which one you removed first. List and feel for any changes as you **slowly** pull the stick out. After you have pulled out one stick, quickly repeat some simple observations before you pull another one out. Things may have changed!

2) Remove each stick one at a time. First predict what you believe will happen the record your new observations and come up with a new layout.
3) **Caution!** You can only conduct this experiment once! You cannot go backwards, so be very thorough on your observations before you move on to the next stick.

Repeat the experiment by getting a new box from the teacher, it will be set up the same way as before. Re-run the experiment and you can either change your methods or alter your observations or you can conduct it in same order to confirm your results. The main thing is to get some more careful observations, because you will not be able to open the box and see what is inside. You will be required to predict a solution as to the whereabouts of the washers solely form your observations and defend it!

Example data sheet.

Simple observations:
Tilted the box front to back: We heard … We felt …
Tilted the box side to side: We heard … We felt…
From these observations we believe there are ___ washers and they are probably located in the box….

Drawing:

Complex observations:
We believe that we will hear … or observe … when stick no# ___ is removed.
When we remove stick no# ___ were heard … We felt…
Then
Tilted the box front to back: We heard … We felt …
Tilted the box side to side: We heard … We felt…
From these observations we believe there are ___ washers and they are probably located in the box….

Drawing:

Conclusion
When you have exhausted your attempts, make one final drawing of what you believe is the arrangement of the washers and comment on some of the major observations that lead you to your conclusion. You do not have to rewrite all your observations!

Light Lab

Name ______________________________ Hour_______

R O Y G B I V	R O Y G B I V
Element ________________	Element ________________
R O Y G B I V	R O Y G B I V
Element ________________	Element ________________
R O Y G B I V	R O Y G B I V
Element ________________	Element ________________
R O Y G B I V	R O Y G B I V
Element ________________	Element ________________

Questions

1.How is light created?

2.Why is there different colors of light?

3.Does each element have the same spectrum? Why or why not?

4.What is the purpose of this lab?

5.What elements do you think make up fluorescent lights. Your best guess with explanation.

Conclusion (On the Back!!)

Table 4: Pre/Post-Test Scores

Question #1

Student	Pre Test Score	Post Test Score
1	4	4
2	4	2
3	4	3
4	4	2
5	3	2
6	4	4
7	2	4
8	3	2
9	4	1
10	4	4
11	2	3
12	4	4
13	4	4
14	4	4
15	4	4
16	4	4
17	4	2
18	4	4
19	2	
20	4	4
21	4	4
22	4	3

Question #2

Student	Pre Test Score	Post Test Score
1	2	1
2	2	3
3	1	1
4	2	2
5	2	2
6	3	2
7	3	1
8	2	2
9	2	2
10	3	3
11	2	2
12	2	2
13	2	2
14	2	1
15	2	1
16	2	1
17	2	2
18	3	2
19	2	
20	2	1
21	3	2
22	2	2

Table 5: Pre/Post-Test Scores

Question #3

Student	Pre Test Score	Post Test Score
1	2	3
2	2	3
3	3	3
4	4	4
5	2	3
6	2	2
7	2	3
8	3	4
9	3	3
10	2	3
11	2	4
12	1	3
13	1	4
14	3	4
15	2	3
16	2	3
17	4	3
18	4	4
19	2	
20	3	3
21	4	3
22	2	3

Question #4

Student	Pre Test Score	Post Test Score
1	3	2
2	3	2
3	2	2
4	3	2
5	4	2
6	0	1
7	3	2
8	2	2
9	3	2
10	4	1
11	4	1
12	3	2
13	3	2
14	3	3
15	4	4
16	3	2
17	4	4
18	4	2
19	3	
20	4	2
21	4	4
22	3	3

Table 6: Pre/Post-Test Scores

Question #5

Student	Pre Test Score	Post Test Score
1	4	3
2	2	2
3	4	4
4	4	4
5	2	4
6	0	4
7	2	3
8	2	1
9	4	4
10	2	2
11	2	2
12	2	2
13	2	4
14	0	1
15	2	4
16	4	3
17	4	4
18	4	4
19	2	
20	2	3
21	0	2
22	1	3

Question #6

Student	Pre Test Score	Post Test Score
1	2	4
2	0	0
3	4	2
4	4	4
5	4	4
6	0	0
7	3	3
8	0	3
9	1	1
10	2	2
11	0	0
12	1	1
13	2	4
14	2	2
15	1	4
16	0	4
17	2	4
18	3	3
19	1	
20	0	3
21	1	3
22	1	4

Table 7: Pre/Post-Test Scores

Question #7

Student	Pre Test Score	Post Test Score
1	3	2
2	2	2
3	2	2
4	2	3
5	3	3
6	0	1
7	1	2
8	2	2
9	0	0
10	2	2
11	2	3
12	0	2
13	1	3
14	3	3
15	2	2
16	2	3
17	3	2
18	1	2
19	2	
20	0	2
21	2	2
22	1	2

Question #8

Student	Pre Test Score	Post Test Score
1	1	3
2	0	0
3	1	1
4	1	3
5	1	1
6	0	0
7	1	0
8	0	2
9	0	0
10	1	3
11	1	2
12	1	1
13	1	4
14	3	1
15	0	2
16	2	3
17	0	0
18	0	3
19	1	
20	1	1
21	1	2
1	1	3

Table 8: Pre/Post-Test Scores

Question #9

Student	Pre Test Score	Post Test Score
1	0	3
2	0	0
3	0	0
4	0	0
5	0	1
6	0	0
7	1	0
8	1	1
9	0	0
10	1	0
11	2	1
12	0	0
13	1	2
14	1	0
15	1	0
16	3	4
17	1	0
18	4	4
19	0	
20	1	0
21	0	1
22	1	1

Question #10

Student	Pre Test Score	Post Test Score
1	1	4
2	2	3
3	3	3
4	2	4
5	3	3
6	1	1
7	1	3
8	2	3
9	2	3
10	3	3
11	3	4
12	2	3
13	2	3
14	3	4
15	3	3
16	3	4
17	3	3
18	3	5
19	2	
20	3	3
21	3	3
22	3	3

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