EFFECT OF INQUIRY LABS ON CONTENT KNOWLEDGE AND INQUIRY SKILLS

by

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Abstract

Inquiry had become a major part of science education in the last decade, as seen by the inclusion in the National Science Standards (NRC1996, 2000). However, the definition of inquiry can vary widely between educators. The structure of inquiry inclusion in the classroom can significantly contribute to the benefits students might receive. Therefore, it is essential that educators prove with data and analysis, that the structure of changes made to curriculum improve student understanding of content and inquiry skills. This study evaluated the inclusion of inquiry labs into the curriculum of two units of Physical Science to determine whether students' understanding of material and inquiry skills improved. Three groups of students were given a pre-test on inquiry skills. These inquiry related skills relate to experimental design, identification of variables and the development of testable scientific questions. The students were also given pre- tests in content related to the two units of study, energy and electricity. Some of the groups performed inquiry labs while others performed a more traditional lab. Post-tests were given in all areas to determine whether an improvement occurred. After analysis it was found that there was no statistically significant improvement on any assessments between the groups that participated in the inquiry lab and the groups that did not participate in inquiry labs. However, anecdotal examination of individual student scores did indicate some improvement.

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Introduction

For many generations of teachers, lab activities have been the cornerstone of the high school science curriculum. The purpose of these activities has always been to give students more hands-on experience with specific content and scientific processes. Originally, these labs were teacher centered activities where a specific set of directions was given and specific outcomes were expected by the teacher. In recent years, many in the educational community have turned away from this traditional "cookbook" style lab to a more process-orientated lab format that is intended to teach scientific reasoning skills. These new types of activities have been given the generic name of inquiry and have become a major part of science teaching standards across the country.

However, inquiry is a hard concept to define and an even harder concept for teachers to incorporate into their classrooms. Some teachers see inquiry as simple hands-on activities while others believe inquiry is a more open-ended student-driven lab format. With the wide variety of definitions available, it can be difficult for a teacher to determine what changes need to be made to the curriculum to best increase student understanding of both content and scientific process.

One major area of possible confusion has been the types of different labs that a teacher could create. Some examples of different types of labs might include a simple hands-on activity or a more complicated project where students use all the steps of the scientific method to determine a conclusion. The problem for teachers is to determine what type of lab would produce more knowledge acquisition and improve scientific processing skills in their students. This study looked at how one specific type of lab affected these skills in a specific group of students.

Literature Review

At the beginning of the twentieth century, the science content taught in most secondary classrooms was viewed as information to be memorized. (Lawson 1995) but as we move toward the future, students need to do more than just memorize facts. The purpose of science education is no longer simply to train future scientists but to help the population as a whole (Wieman 2007). The only way teachers can do this is to keep up with the current trends in science education and incorporate these trends into the classroom. Science teachers occupy a unique position between the theoretical worlds of academia and the everyday reality of the science classroom (Lustick 2009).

As Lustick points out, teachers must keep ahead and aware of the many changing pedagogical practices in order to help students learn effectively. The National Science Standards (NRC 1996) supports this idea by stating that

> "Scientific inquiry refers to the diverse ways in which scientists study the natural world and propose explanations based on the evidence derived from their work. Inquiry also refers to the activities of students in which they develop knowledge and understanding of scientific ideas."

The incorporation of inquiry into these science standards "transforms how students think, so that they can understand and use science like a scientist."(Weiman 2007) However, since its introduction the term "inquiry" has been burdened with an identity crisis. (Barrow 2006)

The National Science Education Standards defines inquiry as…. "a multifaceted activity that involves making observations; posing questions; examining books and other sources of information to see what is already known; planning investigations; using tools to gather, analyze, and interpret data; proposing answers, explanations and predictions; and communicating results." This working definition has provided the basis for curriculum changes that many teachers try to insert into their units and lessons. As an instructional approach, scientific inquiry receives widespread support from educators (Grady 2010). Current learning theories support the use of inquiry-based teaching and learning in science classrooms. (Bransford, Brown & Cook 2000; NRC 2000).

Although inquiry-based instruction is recognized as an effective method of teaching and learning science, there has been limited success in implanting practices in the classrooms. (Choi 2009) "The reasons these practices have not been implemented may stem from teachers' lack of knowledge or from the vagaries of the idea of inquiry."(Lustick 2009) Most teachers associate inquiry primarily with "the scientific method." For some, inquiry happens any time students work in a laboratory setting and for others inquiry is a collaborative student activity. "With so many catch phrases and teaching strategies used in the name of inquiry, how can the term be defined?" (Lustick 2009)

Clearly, research attempting to assess the benefits of inquiry instruction must first define the type of inquiry activities being used in order to compare results between studies (Brickman 2009) "A framework must be provided if science teachers are to teach scientific inquiry skills systematically and at a level appropriate to the intellectual maturity of the student." (Wenning 2007)

For many, the incorporation of inquiry involves the modification of lab activities that students participate in during the course of a unit. With inquiry labs, students take greater control of the entire learning process, from developing problems to designing experimental procedures and drawing conclusions on their own. (Wenning 2007)

These inquiry labs can appear in the curriculum in many different forms. In order to understand and study the effect of inquiry labs, specific definitions must be placed on all of the possible types of activities. The work of Chinn & Malhorta (2002) sets up a nice framework for the continuum of inquiry activities. The most sophisticated of inquiry labs are Authentic Scientific inquiry. “Authentic scientific inquiry is a complex activity, employing expensive equipment, elaborate procedures and theories, highly specialized expertise, and advanced techniques for data analysis and modeling.” (Chinn & Malhorta 2002) Schools lack the time and resources to reproduce such research tasks. Instead, educators must develop simpler tasks that can be carried out within the limitations of space, time, money, and expertise that exist in the classroom. (Chinn & Malhorta 2002).

On the other end of the inquiry continuum is the simple experiment. In simple experiments, students conduct a straightforward experiment, usually evaluating the effects of a single independent variable on a single dependent variable. (Chinn & Malhorta 2002) As Chinn & Malhorta point out, “simple inquiry tasks may not only fail to help students learn to reason scientifically; they may also foster a nonscientific epistemology in which scientific reasoning is viewed as simple task focused on surface level observation.”

In between the two ends of this continuum are many different variations of inquiry activities. One type is called the Guided Inquiry lab. In Guided Inquiry labs, the instructor poses an initial problem as in a simple experiment lab but then guides the students to selecting the variables, planning the procedure controlling variables, planning measures, and helps students arrive at a solution (Buck, Bretz & Towns 2008) The Guided Inquiry approach also provides more direction to students who may be poorly prepared to tackle inquiry problems without prompts and instruction because of lack of experience , knowledge or because they have not reached the level of development required for abstract thought. (Lawson 1980) Guided Inquiry is most appropriate for students at an introductory high school level. The goal is to develop relatively simple school inquiry tasks that capture core components of scientific reasoning. Through carrying out these tasks, students are expected to learn to reason scientifically.

(Chinn& Malhorta 2002) This study used a Guided Inquiry lab approach to empirically show whether students' scores changed on pre- and post-tests where guided inquiry labs were involved.

Definition of Terms

Guided Inquiry Lab- A lab that does not have a specific questions or written procedural directions for the student to follow. These labs let the students use the skills they have acquired from the unit to determine a problem, pick independent and dependent variables , create a hypothesis, develop a procedure and come to a conclusion on their own. This definition is derived from the work of L. B. Buck and associates in *Characterizing Levels of Inquiry* (Buck 2008)

Traditional Cookbook Lab- A lab that specifically directs student to find the answer a questions using one method dictated by the teacher and answer specific questions in order to reinforce a concept. This definition is derived from the work of C.A. Chinn and B.A. Molhorta in *Epistemologically authentic inquiry in schools: A theatrical framework for evaluating tasks* (Chinn & Molhorta 2002)

Inquiry Skills- These are skills that students develop and apply when using the scientific method. They include but are not limited to: how to identify variables, how to ask good testable questions, how to set up an experiment so only one variable is being tested.

Statement of Problem/Justification

With so many different definitions for inquiry, it can be extremely difficult for a teacher to determine exactly how to modify labs and activities to best incorporate the standard for inquiry. Definitive quantitative evidence of the effects of specific lab types on student learning is hard to find. The problem remains that much research has looked at the effect of inquiry but not on how different types of labs affect student skills.

The purpose of this study was to look at two different lab types (traditional cookbook versus guided inquiry) and determine whether these types of lab structures had any influence on students' acquisition of inquiry skills, energy conceptual understanding, and electrical understanding.

Research Question/Hypothesis

The question undertaken by this study was: Will including different types of labs, traditional cookbook versus guided inquiry, significantly increase student scores on tests for inquiry skills, energy concepts, and electricity concepts? My assertion was that the inclusion of inquiry labs into the curriculum for energy and electricity units would produce significant increases in student scores on knowledge-specific tests and inquiry skills tests. Inquiry is an important part of the scientific process so it appears that inclusion of these types of labs should increase student mastery. Therefore, students who receive the guided inquiry labs would score higher on all tests compared to students who did not participate in the inquiry labs.

Experimental Method

To experimentally determine whether guided inquiry lab would have more of an effect on content knowledge and inquiry skills, a quasi-experimental nonequivalent-group design was devised. Three physical science classes were available, but conditions did not allow for random assignment of the group members. These conditions will be discussed in the limitation section. The design itself entails a pre-test, mid-test and post-test for three groups as indicated by the following notation:

Group 1	O	X	O		O
Group 2	O		O	X	O
Group 3	O	X	O	X	O

An “O” depicts that a measurement has been made, and “X” depicts the participation in an inquiry lab. All groups were provided identical notes, examples, homework assignments, quizzes, and the same opportunities to ask questions for each unit.

For the energy unit, groups 1 and 3 were assigned a guided inquiry lab toward the end of the unit while group 2 was given a very traditional cookbook style lab. For the electricity unit, groups 2 and 3 were given guided inquiry labs and group 1 participated in a traditional cookbook lab. Group 3 participated in two inquiry labs during the duration of this study and therefore was expected to perform the best of all groups.

Participants

The participants in this study were 42 high school freshman students enrolled in three physical science classes. The classes contained 20 to 24 students each but many did not return the permission slips for this research so the actual number of students who participated was 14-16 per class period. The Physical Science class is a 45 minute, daily general education course that contains a wide variety of students with many different backgrounds and educational levels. Group 1 (14) was the first hour class, group 2 (16) was the fourth hour class and group 3 (14) was the seventh hour class. The statistical equality and inequality of these groups will be discussed in the results section.

Measures/Materials

During this study, students were tested using three different assessment tools. The first was the inquiry skills test that was modified from a larger assessment tool called Physical Science Inquiry Skills Test. (www.dcraig.us/ITG.pdf) The larger test is found in Appendix A. The modified version of this assessment is found in Appendix B. Modifications were made to eliminate questions about specific physical science content and focus only on the inquiry skill questions. This was used as the inquiry skills pre-test, mid-test and post-test. Each group of students took the same assessment three times.

The second measure was an energy multiple choice assessment that was created using the test bank software from the Prentice Hall Physical Science: Concepts in Action textbook (Wysession, *et al*. 2006). This assessment was given as a pre-test for energy and a post-test for energy. Each student took this assessment twice. This assessment can be found in Appendix C.

The third measure was an electricity multiple choice assessment that was created using the test bank software from the Prentice Hall Physical Science: Concepts in Action (Wysession, *et al.* 2006). This assessment was given as a pre-test for electricity and a post-test for electricity. Each student took this assessment twice. This assessment can be found in Appendix D.

The treatment for these groups was an energy inquiry lab, an electricity inquiry lab or both. The two inquiry lab directions are included in Appendices E and F. These two guided inquiry labs have a similar handout and were presented to each class in a similar way. These labs required students to determine a problem to test, write a hypothesis, create a procedure and analyze the results. The two traditional cookbook labs are included in Appendices G and H. These labs gave specific directions and required the students to perform data collection and then answer a series of questions.

Procedure

This experiment was conducted over a nine week period starting April 4th of 2011 and running until June 3rd of 2011.The experiment began with the administration of the first set of assessments which included the inquiry skills test and the energy pre- test. After the pre-tests, materials were presented for a unit on energy. All groups were presented with the information in a similar fashion and all homework was identical.

Toward the end of the unit, groups 1 and 3 performed the guided inquiry lab on energy. This inquiry lab was presented by asking the questions: “What happens to a marble as it rolls down a ramp?” The class created a list of possible things we could change about the ramp or marble. These were determined to be the independent/manipulated variable we could use for the experiment. Then the class created a list of things we could measure for a marble rolling down a ramp and these became our dependent/responding variables for the lab. The students then partnered up into lab groups of two or three students and had to use these two columns of variables to create a lab investigation question and hypothesis.

At the end of the energy unit, group 2 was presented with the traditional cookbook lab on energy. The introduction to this lab included going over materials and reading the procedure. Then the students were allowed to partner up into lab groups of two or three and proceed with the activity which included performing the procedure, collecting data and answering questions. After all groups had completed the labs, students retook the Inquiry skills test and the energy post–test.

Students were then given the electricity pre -test. All classes then continued with the unit on electricity where all students were given identical notes and assignments. Toward the end of the unit, groups 2 and 3 were given the guided inquiry electricity lab which included posing the question: “How does a circuit change when equipment is added to it?” The class created a list of things that could be changed about a circuit and these became our independent/manipulated variables for the lab. Then the class created a list of things we could measure for a circuit and these became our dependent/responding variables for the lab. The students then partnered up into lab groups of two or three students and had to use these two columns of variables to create a lab investigation question and hypothesis.

Group 1 was introduced to the traditional "cookbook" electricity lab. The introduction to this lab included going over materials and reading the procedure. Then the students were allowed to partner up into lab groups of two or three and proceed with the activity which included performing the procedure, collecting data and answering questions.

After this electricity unit, students were again given the Inquiry Skills test and the electricity post-test. The percentage scores for correct answers were calculated and all raw data appears in Appendix I.

Limitations

There are several experimental constraints that made absolute conclusions about the results of this study and its application unreliable.

First, data acquisition was limited to only 2 units during 9 weeks of a quarter. Moreover, the population was small, consisting of a total of only 42 freshman level students. The vast differences in background and prior knowledge of these students in a general education class may not be representative of the entire high school, let alone a larger general population of students who might benefit from the treatment.

Furthermore, students were not randomly assigned into the groups. The students were scheduled into their specific section due to other constraints in the school master schedule. This fact may have made the groups significantly different than the freshman population. For example, first hour was at the same time as band (which is only held once a day) and that means no students from band were in this section. This type of non-equivalent group design is susceptible to inaccuracies and false conclusions.

The assessments themselves were vulnerable to limitations. The tests created for this study were not tested prior to this study to determine effectiveness. Problems with the tests themselves could contribute to problems for this study. The assessments were repeated several times during the study so students did see the same question repeatedly. To try to eliminate this problem, no students were given the answers to any assessment or saw their scores on any of the tests. The tests were corrected and scored only after the students were no longer in the specific class and had left school for summer vacation. Therefore, the students lost the usual benefit of learning from assessment feedback.

Also, the pre- and post-assessments were not counted toward a grade for the students in my course. Extra credit was given for completing the assessment. However, many students may have not done their best work without the threat of a grade to force the proper amount of effort. This meant the answers may be more of a reflection of guessing rather than what they actually knew.

Another issue was the completion of the tests. At the mid-point assessment the students were required to complete three tests. This was a long task that took two days of class time. Many students seemed to have test fatigue toward the end of the testing period. Students seemed to give up on many of the questions and appeared to put down random answers. This was especially evident on the Electricity pre-test which was at the end of the testing period.

The last limitation may have been the experimental design itself. None of the groups in this study was exempt from all inquiry labs. This meant there was no real control group. The reason for this omission, or my justification for it, was for the benefit of the students. All the background research showed the educational benefits of guided inquiry were significant, and as an educational professional, I felt I would have been delinquent in my duties if all of the groups had not had at least some experience with this type of lab.

Results

The average exam percentages representing the pre-tests and post-tests and the confidence intervals for all groups are in Table 1.

Table 1: Mean Percentages with 95% confidence intervals

	Inquiry			Energy		Electricity	
	Pre Test	**Mid Test**	**Post Test**	**Pre Test**	**Post Test**	**Pre Test**	**Post Test**
Group 1	**57.1 ±7.7**	**53.7 ±10.7**	**53.6 ±9.8**	**35.5 ±6.6**	**53.2 ±7.7**	**25.8 ± 3.7**	**57.9 ±7.9**
Group 2	**51.9 ±8.7**	**63.9 ±9.7**	**70.5 ±8.1**	**36.2 ±9.1**	**64.3 ±8.8**	**63.3 ±7.3**	**67.1 ±6.2**
Group 3	**43.9 ±13.0**	**55.5 ±9.9**	**61.8 ±8.9**	**35.7 ±9.2**	**53.9 ±10.1**	**44.0 ±8.7**	**58.6 ±7.2**

In order to compare these pre- and post-tests, it had to be determined if these three groups were statistically equivalent on all three pre-tests. If the groups were not statistically equivalent on the pre-tests then the post-test scores could not provide useful information. The t-test was performed for each group and the t value and p values were produced (Table 2).

These groups were *assumed* to have no significant statistical difference and would be statistically equivalent. In order for two groups to be statistically similar the resulting t-values generated from the data must be larger than the critical t value listed based on a given number of degrees of freedom. Also, since we used 95% confidence interval, we looked for a p-value that was less than 0.05.

After doing several t-test calculations (Table 2) all of the groups had a p value of greater than 0.05 for the energy and the inquiry pre-tests which means there is no significantly statistical difference between all groups of these tests. A problem however arose with the electricity pre-test assessment. The average score on this pre-test varied widely and after further analysis with the t-test calculation (Table 2) it was determined that all three groups are statistically different because the p values are all below 0.05 and about the critical t value. Therefore the post-test data of the electricity has been excluded from further analysis.

Table 2: t-test comparison of pre-test score for inquiry, energy and electricity

Group Comparisons	INQUIRY PRE TEST			ENERGY PRE TEST			ELECTRICITY PRE TEST		
	t calc	*p-value*	*t-crit*	*t calc*	*p value*	*t-crit*	*t calc*	*p value*	*t-crit*
Group 1 & 2	1.124	0.27	2.05	-0.49	0.64	2.05	-8.88	2.2E-08	2.06
Group 2 &3	0.66	0.51	2.05	0.54	0.59	2.06	3.11	0.0045	2.06
Group 1&3	1.49	0.15	2.06	0.15	0.88	2.06	-3.76	0.0014	2.06

Note. The t-test was conducted at the 95% confidence interval (α = .05).
Negative t-stat values indicate that the treatment group had a higher mean score.
a_n = 14 with 26 df and a critical t is for a two-tailed test.
Group 1= cookbook lab then inquiry lab
Group 2= inquiry lab then cookbook lab
Group 3= two inquiry labs

After the inquiry pre-test evaluation was complete, the inquiry pre- test was compared to the inquiry mid- test. The results of these t-test comparisons can be found in Table 3. For groups 1 and 3 the p value was greater than 0.05 and larger than the critical t which meant that there is not statistical difference between the pre and mid tests for these groups. Group 2 had a p value less than 0.05 and was less than the critical t value for the inquiry pre- and mid-test comparison and the pre-/ post- test comparison. Group 2 was statistically different for both comparisons and the average scores increased from both pre- to mid- and pre- to post- tests.

Table 3: t-test comparison of inquiry pre-mid and mid-post

Group	INQUIRY PRE- MID COMPARISON			INQUIRY PRE-POST COMPARISON		
	t-calc	*p value*	*t-crit*	*t-calc*	*p value*	*t-crit*
Group 1	0.38	0.7	2.06	0.45	0.65	2.07
Group 2	-2.16	0.038	2.05	-3.18	0.0033	2.05
Group 3	-1.39	0.17	2.07	-2.12	0.036	2.08

Note. The t-test was conducted at the 95% confidence interval (α = .05).
Negative t-stat values indicate that the mid or post group had a higher mean score.
a_n = 14 with 26 df and a critical t is for a two-tailed test.
Group 1= cookbook lab then inquiry lab
Group 2= inquiry lab then cookbook lab
Group 3= two inquiry labs

The last comparison was between the pre- and post- test for the energy assessment. The p-values for the t-test of all three groups were all less than 0.05 and greater than the critical t value of 2.16. This showed that all groups were statistically different and all three groups had increased average scores.

Table 4: t-test comparison of energy pre- and post-test

Group	ENERGY PRE- POST COMPARISON		
	t-calc	*p value*	*t-crit*
Group 1	-3.61	0.001	2.06
Group 2	-4.56	0.000485	2.05
Group 3	-2.57	0.016	2.07

Note. The t-test was conducted at the 95% confidence interval (α = .05).
Negative t-stat values indicate that post group had a higher mean score.
a_n = 14 with 26 df and a critical t is for a two-tailed test.
Group 1= cookbook lab then inquiry lab
Group 2= inquiry lab then cookbook lab
Group 3= two inquiry labs

Analysis

After analysis, group 1 and group 3 showed no statistically significant improvement from the inquiry pre-test to the inquiry mid-test. Between these two tests both group 1 and group 3 participated in an inquiry lab. Group 2 showed statistically significant improvement from the inquiry pre-test to the inquiry mid-test. Between these two tests, group 2 participated in the cookbook style lab. So the only group that showed improvement from inquiry pre-test to inquiry mid-test was the group that did not do the inquiry lab while the groups that participated in the guided inquiry lab showed no improvement in average scores

The reasons for this unexpected result could stem from the overall difference in group make up due to the non random nature of class scheduling. Also, there were some differences in class discussion between groups that might have given rise to a better understanding of inquiry from pre-to mid-test for group 2. These unforeseen factors made the initial round of assessments for inquiry inconsistent with my hypothesis.

As the experiment progressed, group 2 and group 3 now had the chance to participate in the inquiry labs while group 1 participated in the cookbook lab. Group 2 and 3 show a statistically significant difference in scores from inquiry pre-test to inquiry post-test.

These results seemed inconsistent for group 3 specifically. Between pre- and mid-test group 3 performed an inquiry lab but had no statistically significant increase in scores. However, the inquiry lab performed between the mid-test and the post-test *did* result in an increase in scores. To be consistent with the hypothesis group 3 should have seen improvements on both the mid- and post- inquiry test. Additionally, group 1 saw no improvement during the length of the entire study even though they had participated in an inquiry lab at least once.

These inconsistencies may be attributed to the repetition of the assessments through the study. Even though students never saw answers to these assessments, the simple fact that they saw the same questions over and over may have changed the way they responded.

The energy test scores were also analyzed and the t-test scores for all groups showed that there was a statistically significant difference between the pre- and post- tests for all groups. This meant that the guided inquiry and traditional labs both gave improvement in test scores and that the implementation of additional inquiry did not significantly increase scores on the content exams.

These findings suggest that the hypothesis presented in this study was incorrect. However, if student scores are looked at anecdotally, there were many students that saw significant improvement of their individual scores even if the class averages did not reflect improvement. An example for group 1, one student had an inquiry pre test score of 57.1% and then after the inquiry lab the score increase to 82.9 %. As a teacher, I'm pleased with this kind of improvement even if the class average was not strongly affected. Several students in group 1 showed individual score increases because of the inquiry activity. These individual increases showed that some learning did come from these activities and that this is definitely a step in the right direction. For this reason, the statistics for the group average may mask how this type of lab really helped individual students.

These individual scores lead me to believe that the inquiry labs *do* make a difference but with such a small sample size one or two outliers in the data could significantly affect the statistics and therefore showed no significant difference in averages when there really was an important impact on student success. Student scores on the inquiry and energy tests did not show, however, overall average improvement due to the inclusion of guided inquiry labs compared to traditional cookbook labs but there were many examples of individual improvement (Appendix I).

A definitive conclusion would probably need more academic units of study over a longer period of time with more students but with the limited scale of this study it appeared the inclusion of guided inquiry lab create the minimal of statistically credible effects.

The reasons for this could include the structure of the guided inquiry labs. The students may have needed more aspects of authentic inquiry (Chin & Malhorta 2008) in order to truly receive the benefit of the process. Also, it appeared from this study that just simply inclusion of lab modifications might not be enough to drastically improve student understanding. Other aspects of the curriculum might also need to change in order to adequately increase student success such as lesson plan structure or adding more authentic inquiry. And lastly, the very small student populations could have drastically influenced the results to show no improvement.

Teachers are under the assumption that more inquiry means more understanding. However, based on the results of this study, this method of inquiry incorporations does not produce the levels of results expected. There were some incidental improvement in student's scores which is good for those students, but the overall averages did not see significant improvement. The hypothesis for this experiment was rejected but it appears that more testing would need to be done.

Applications of this study would imply additional changes would be needed in order to improve student scores. One possible suggestion would be to include modified lesson structure called 5E. This type of inquiry based practice can be seen in the article "Doing Science: The Process of Scientific Inquiry" from Biological Science Curriculum Study (BSCS 2005) Lessons are broken down into five parts: Engage, Explore, Explain, Elaborate and Evaluate. This method more closely follows an inquiry framework. This change to lesson plan structure might improve student scores. Other suggestions would be to changes the labs to more closely model Authentic Inquiry (Chinn & Malhorta 2008). Also, the assessments used in this study might need more rigorous testing to determine the true usefulness of the scores. This study needs to be performed again after these changes are made to determine effectiveness of inquiry in the classroom.

Summary

This study sought to answer the question: Will incorporating guided inquiry labs in to physical science units increase scores on assessments in content and inquiry? Based on the statistical information collected it appears that the incorporation of inquiry lab in the current form did not have a statistically significant impact on average student scores for the three groups studied.

However, there was some individual improvement which suggested that more testing needs to be done. As a teacher, I would continue to included these types of labs and make other modifications to the curriculum and then rerun this experiment.

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Appendix A: Original Unmodified Physical Science Inquiry Test

Physical Science Inquiry Skills Test Questions Aligned to Standards

Standard I.A. Identify questions and concepts that guide scientific investigations: Experimental design should demonstrate logical connections between a knowledge base and conceptual understanding.

1. Demonstrate an understanding of the process of developing scientific hypotheses (e.g. formulate a testable hypothesis based on literature research and prior knowledge, and select the correct form for a hypothesis statement based on a given scenario.)

______1. Which question cannot be answered by an experiment?

(A) Does penicillin kill Salmonella bacteria?
(B) Is rabies caused by a virus?
(C) Did a comet impact kill the dinosaurs?
(D) Can radiation cause cancer?

Answer: C	Source: *Holt Science*

______2. Hypotheses may arise from

(A) prior knowledge
(B) logical inferences
(C) imaginative guesses
(D) all of the above

Answer: D	Source: *Holt Science*

______3. Refer to the table and question below:

Time Required for Water Evaporation

Container	A	B
Volume of Water (mL)	25	25
Temperature (°C)	−15	25
Time Required (h)	72	24

28 The table shows times required for water to evaporate from identical containers. Which of these is the best question to ask before developing a reasonable hypothesis to explain the data?

F Why does a lower temperature slow the rate of evaporation?

G What is the boiling point of the water after both samples are heated?

H Why does water exist as a solid at −15°C and as a liquid at 25°C?

J How does the rate of evaporation change when a different container is used?

Answer: F	Source: NY Regents Chemistry

______3b. Nancy has been playing with a water rocket. She can change the amount of water and the angle of release of the rocket. She can also change the weight of the rocket. Which of the following is a hypothesis she could test about these variables?

(A) Rockets with warm water will rise higher than rockets with cold water.
(B) Rockets with four tail fins will rise higher than rockets with two tail fins.
(C) Rockets with pointed nose cones will rise higher than rockets with rounded nose cones.
(D) Rockets with more water will rise higher than rockets with less water.

Answer: D	Source: U of Ga. Integrated Science Pr

3c. A police chief is concerned about reducing the number of speeding autos. The thinks several factors may affect auto speed. Which of the following is a hypothesis he could test about how fast people drive?
(A) The younger the drivers, the faster they are likely to drive.
(B) The larger the autos involved in an accident, the less likely people are to get hurt.
(C) The more policemen on patrol, the fewer the number of auto accidents.
(D) The older the autos, the more accidents they are likely to be in.

Answer: A	Source: U of Ga. Integrated Science Proc

2. Identify and select experimental variables (independent and dependent) and devise methods for controlling relevant conditions.

______4. In an experiment to determine the effects of radiation on the germination of seeds, the independent variable would be
(A) the amount of radiation
(B) the germination rate of seeds
(C) the temperature of the soil
(D) the amount of water added to the seeds

Answer: A	Source:

______5. In the above experiment, factors that should be controlled are

(A) A & B
(B) A &: C
(C) B & D
(D) C & D

Answer: D	Source:

______6. The dependent variable in an experiment is
(A) the part of the experiment that the scientist changes.
(B) what changes as a result of the experiment.
(C) an educated guess about what might happen.
(D) one of the steps in the scientific method.

Answer: B	Source: *Holt Science*

______7. A controlled experiment allows the scientist to isolate and test

(A) a conclusion
(B) a mass of information
(C) several variables
(D) a single variable

Answer: D	Source: *Holt Science*

______8. A scientist wants to determine if a type of yeast will make a cake rise. The scientist bakes one cake with the yeast and one cake with no yeast. Which of the following is the independent variable in this experiment?

(A) the scientist
(B) the yeast
(C) the cake with the yeast
(D) the cake without the yeast

Answer: B	Source: *Holt Science*

______9. The variable that is changed by the scientist and measured in the experiment is the
(A) independent variable
(B) dependent variable
(C) controlled variable
(D) experimental variable

Answer: A	Source: *Holt Science*

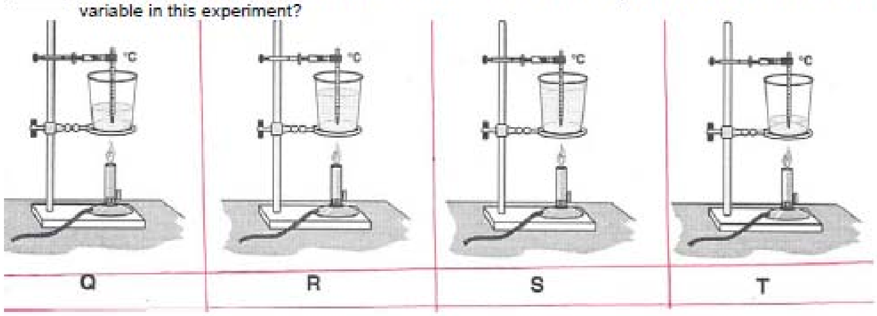
______9a. John wanted to find out which laundry soap was best for removing grass stains. Each soap was mixed with warm water. It was then used to scrub a piece of grass-stained cloth for 1 minute. Then the amount of stain left on the cloth was measured. What was the dependent variable?
(A) water temperature
(B) Laundry soap
(C) amount of stain left on the cloth
(D) scrubbing time for each cloth

Answer: C	Source: U of Ga. Integrated Science Proc

______9b. What was the independent variable in the above experiment?
(A) scrubbing time
(B) water temperature
(C) amount of water
(D) type of laundry soap

Answer: D	Source: U of Ga. Integrated Science Pro

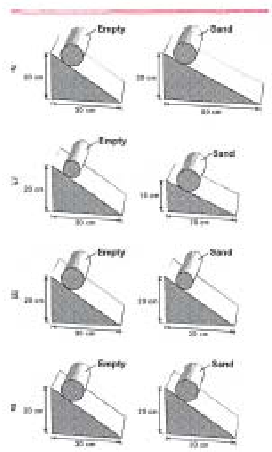
______9c. The temperature of the water in each container is recorded every minute. Which variable is the independent variable in this experiment?



(A) the shape of the container
(B) the heat of the burner
(C) the volume of water heated
(D) the exposed surface area

Answer: C	Source: Texas Test

9d. Students want to find out if an empty can rolls down a ramp faster than a can filled with sand. Which of these would be the fairest way to find out?



Answer: J	Source: Virginia Science Test

B. Design and Conduct Investigations: Science builds on prior knowledge, thus prior knowledge about major concepts, laboratory apparatus, laboratory techniques, and safety should be used in designing and conducting a scientific investigation.

1. Demonstrate an understanding of the process of testing scientific hypotheses (e.g. design and conduct a scientific investigation based on the major concepts in the area being studied.)

______10. Scientific hypotheses are most often tested by the process of
(A) communicating (C) experimenting
(B) inferring (D) analyzing data

Answer: C	Source: *Prentice Hall Science*

_______11. In science, a hypothesis is useful only if

(A)	it is proven correct.	(C)	It can be tested.
(B)	It can be proven incorrect.	(D)	The explanation is already known.

Answer: C	Source: *Prentice Hall Science*

_______12. The ability to reproduce results is an important part of any

(A)	hypothesis	(C)	law
(B)	theory	(D)	experiment

Answer: D	Source: *Holt Science*

_______13. The work of scientists begins with

(A)	testing a hypothesis	(C)	creating experiments
(B)	careful observations	(D)	drawing conclusions

Answer: B	Source: *Prentice Hall Science*

_______14. A planned procedure to test a hypothesis is called a(n)

(A)	prediction	(C)	control
(B)	experiment	(D)	variable

Answer: B	Source: *Holt Science*

_______15. An experiment

(A) must always be done in a laboratory
(B) is best done if only one variable is tested for at a time.
(C) can be done only by direct observation.
(D) must always be done in the field.

Answer: B	Source: *Prentice Hall Science*

_______16. One advantage of recording data accurately is that you can

(A) control the results
(B) repeat the experiment
(C) use the data to prove or disprove your hypothesis.
(D) Avoid having to analyze your data.

Answer: B	Source: *Holt Science*

_______17. Scientists communicate their findings to other scientists in order to

(A) keep others from studying the same problem.
(B) allow others to check and evaluate their work.
(C) gain fame for themselves.
(D) force others to accept their results.

Answer: B	Source: *P.H. Science*

_______18. Before forming a hypothesis, a scientist must first

(A) define a problem.
(B) disprove a theory
(C) collect information
(D) define the variables.

Answer: D	Source: *Holt Science*

_______19. Scientists today learn about the world by

(A) using untested hypotheses to revise theories.
(B) observing, measuring, testing, and explaining ideas.
(C) formulating conclusions without testing them.
(D) changing laws.

Answer: B	Source: *Holt Science*

_______20. A controlled experiment allows the scientist to isolate and test

(A)	a conclusion	(C)	several variables

Answer: B	Source: U of Ga. Integrated Science Process Skill Test

_______24b. Jim thinks that the more air pressure in a ball, the higher it will bounce. He collects some balls and an air pump with a pressure gauge. How should Jim test this?
(A) Bounce balls with different amounts of force from the same height.
(B) Bounce balls having different air pressures from the same height.
(C) Bounce balls having the same air pressure at different angles from the floor.
(d) Bounce balls having the same amount of air pressure from different heights.

Answer: B	Source: U of Ga. Integrated Science Process Skill Test	

______24c. Tom wanted to test how effective dishwashing liquids were. Which of the following is the BEST question for Tom to ask?
(A) What color are the dishwashing liquids?
(B) Which dishwashing liquid is better?
(C) Which dishwashing liquid washes dishes cleaner?
(D) Which dishwashing liquid is oldest?

Answer: C	Source: U of Ga. Integrated Science Process Skill Test	

______24d. John wonders what affects the time it takes ice cubes to melt. He decides to test whether the shape of an ice cube affects the time it takes to melt. How could he test this?
(A) Use 5 ice cubes. All should have a different shape and weight. Use 5 identical jars, all at the same temperature. Observe the melting time of the ice cubes.
(B) Use 5 ice cubes. All should have the same shape, but different weights. Use 5 identical jars, all at the same temperature. Observe the melting time of the ice cubes.
(C) Use 5 ice cubes. All should have the same weight, but a different shape. Use 5 identical jars, all at the same temperature. Observe the melting time of the ice cubes.
(D) Use 5 ice cubes. All should have the same weight, but a different shape. Use 5 identical jars, each at a different temperature. Observe the melting time of the ice cubes.

Answer: C	Source: U of Ga. Integrated Science Proce

24e. Some students are studying vitamins. They want to do an experiment. Which is the <u>best</u> question for them to experiment with?
(A) Does vitamin A or C dissolve faster?
(B) Why do vitamins dissolve in water?
(C) How do vitamins work in humans?
(D) Does vitamin C prevent a cold?

Answer: A	Source: U of Ga. Integrated Science Proce

______24f. Some students wanted to do a scientific experiment. Which question below could they most easily try to answer through an experiment?
(A) Why do magnets work?
(B) Why do plants grow most during the summer?
(C) What factors affect plant growth during the year?
(D) What is the affect of different amounts of water on plant growth?

Answer: D	Source: U of Ga. Integrated Science Proce

24g. Tom wants to test this hypothesis: "The hotter the water, the faster sugar will dissolve." Which would be the best plan to test this?
(A) Set up 4 jars of water. Have #1 at 20^{0}C, #2 at 40^{0}C, #3 at 60^{0}C, and #4 at 80^{0}C. Use one teaspoon of sugar in each jar. Time the dissolving.
(B) Set up 2 jars of water. Have # 1 at 20^{0}C, #2 at 30^{0}C. Use one teaspoon of sugar in each jar. Time the dissolving.
(C) Set up 3 jars of water all at the same temperature. Put one teaspoon of sugar in each jar. Heat jar #1 over low heat. Heat jar #2 over high heat. Do not heat jar #3. Time each one until the sugar dissolves.
(D) Set up 4 jars of water. In jar #1, put 1 teaspoon of sugar. In jar #2, put two teaspoons of sugar. In jar #3, put three teaspoons of sugar. In jar #4, put four teaspoons of sugar. Time all 4 until the sugar has dissolved.

Answer: A	Source: U of Ga. Integrated Science Proce

Appendix B: Inquiry Skills (Pre, Mid and Post) Test

Inquiry Skills Test

______1. Which question cannot be answered by an experiment?

(A) Does penicillin kill Salmonella bacteria? (C) Did a comet impact kill the dinosaurs? (B) Is rabies caused by a virus? (D) Can radiation cause cancer?

______2. Hypotheses may arise from

(A) prior knowledge (C) imaginative guesses
(B) logical inferences (D) all of the above

______3. Refer to the table and question below:

Time Required for Water Evaporation

Container	A	B
Volume of Water (mL)	25	25
Temperature (°C)	−15	25
Time Required (h)	72	24

The table shows times required for water to evaporate from identical containers. Which of these is the best question to ask before developing a reasonable hypothesis to explain the data?

A Why does a lower temperature slow the rate of evaporation?

B What is the boiling point of the water after both samples are heated?

C Why does water exist as a solid at −15°C and as a liquid at 25°C?

D How does the rate of evaporation change when a different container is used?

______4. Nancy has been playing with a water rocket. She can change the amount of water and the angle of release of the rocket. She can also change the weight of the rocket. Which of the following is a hypothesis she could test about these variables?

(A) Rockets with warm water will rise higher than rockets with cold water.
(B) Rockets with four tail fins will rise higher than rockets with two tail fins.
(C) Rockets with pointed nose cones will rise higher than rockets with rounded nose cones.
(D) Rockets with more water will rise higher than rockets with less water.

_______5. A police chief is concerned about reducing the number of speeding autos. The thinks several factors may affect auto speed. Which of the following is a hypothesis he could test about how fast people drive?

(A) The younger the drivers, the faster they are likely to drive.
(B) The larger the autos involved in an accident, the less likely people are to get hurt.
(C) The more policemen on patrol, the fewer the number of auto accidents.
(D) The older the autos, the more accidents they are likely to be in.

______6. In an experiment to determine the effects of radiation on the germination of seeds, the independent variable would be

(A) the amount of radiation
(B) the germination rate of seeds
(C) the temperature of the soil
(D) the amount of water added to the seeds

______7. In the above experiment, factors that should be controlled are

(A) A & B
(B) A &: C
(C) B & D
(D) C & D

______8. The dependent variable in an experiment is

(A) the part of the experiment that the scientist changes.
(B) what changes as a result of the experiment.
(C) an educated guess about what might happen.
(D) one of the steps in the scientific method.

______9. A controlled experiment allows the scientist to isolate and test

(A) a conclusion
(B) a mass of information
(C) several variables
(D) a single variable

______10. A scientist wants to determine if a type of yeast will make a cake rise. The scientist bakes one cake with the yeast and one cake with no yeast. Which of the following is the independent variable in this experiment?

(A) the scientist
(B) the yeast
(C) the cake with the yeast
(D) the cake without the yeast

______11. The variable that is changed by the scientist and measured in the experiment is the

(A) independent variable
(B) dependent variable
(C) controlled variable
(D) experimental variable

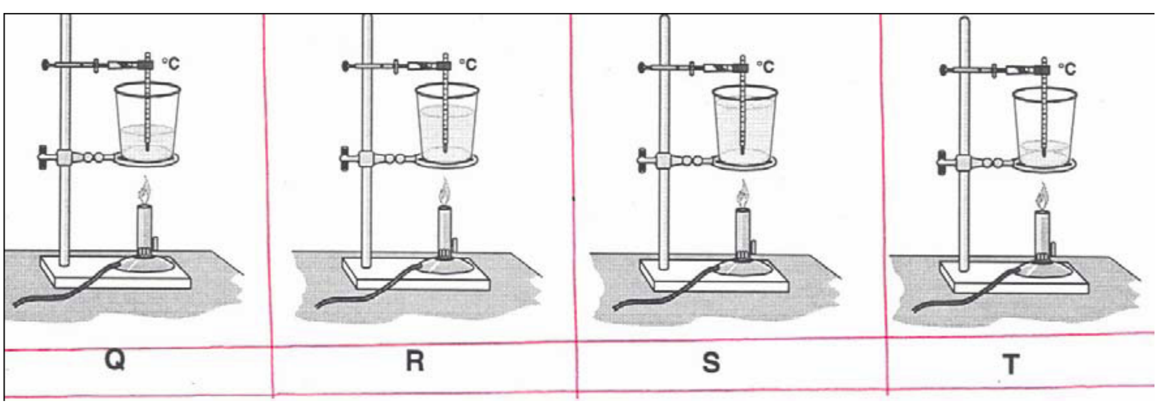
______12. John wanted to find out which laundry soap was best for removing grass stains. Each soap was mixed with warm water. It was then used to scrub a piece of grass-stained cloth for 1 minute. Then the amount of stain left on the cloth was measured. What was the dependent variable?

(A) water temperature
(B) Laundry soap
(C) amount of stain left on the cloth
(D) scrubbing time for each cloth

______13. What was the independent variable in the above experiment?

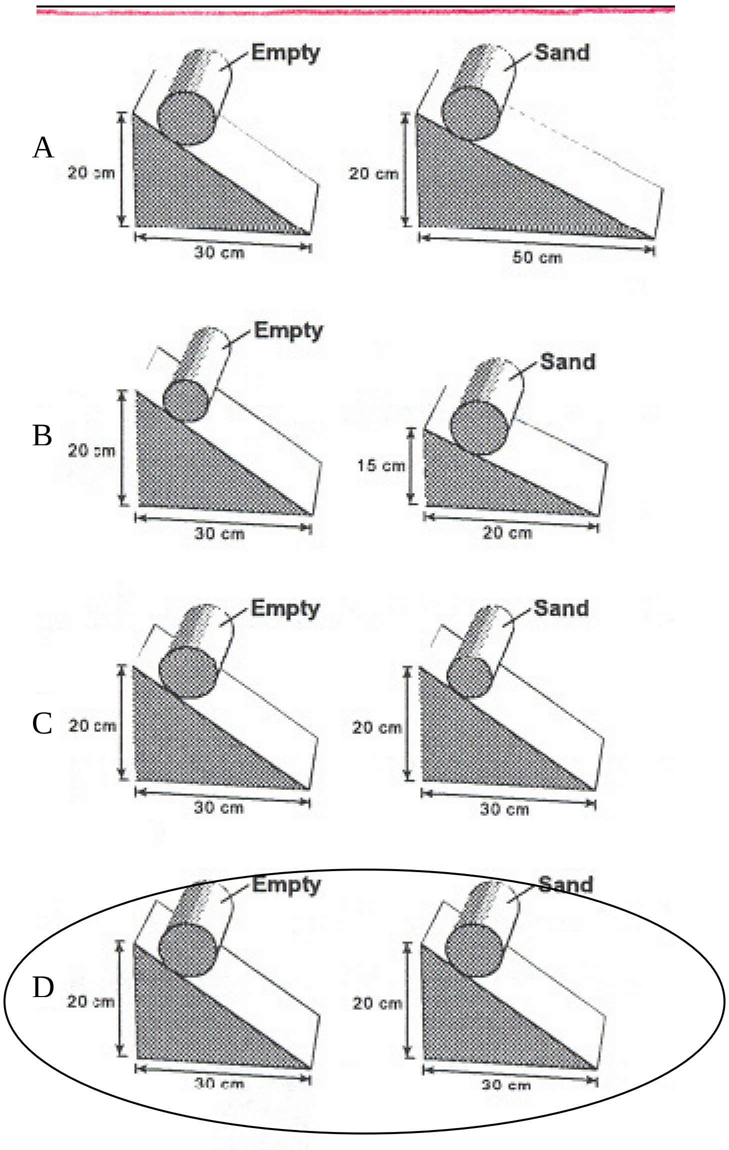
(A) scrubbing time
(B) water temperature
(C) amount of water
(D) type of laundry soap

______14. The temperature of the water in each container is recorded every minute. Which variable is the independent variable in this experiment?



(A) the shape of the container
(B) the heat of the burner
(C) the volume of water heated
(D) the exposed surface area

_______15. Students want to find out if an empty can rolls down a ramp faster than a can filled with sand. Which of these would be the fairest way to find out?



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(A) communicating (C) experimenting
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______17. In science, a hypothesis is useful only if

(A) it is proven correct. (C) It can be tested.
(B) It can be proven incorrect. (D) The explanation is already known.

______18. The ability to reproduce results is an important part of any

(A) hypothesis (C) law
(B) theory (D) experiment

______19. The work of scientists begins with

(A) testing a hypothesis (C) creating experiments
(B) careful observations (D) drawing conclusions

______20 A planned procedure to test a hypothesis is called a(n)

(A) prediction (C) control
(B) experiment (D) variable

______21. An experiment

(A) must always be done in a laboratory
(B) is best done if only one variable is tested for at a time.
(C) can be done only by direct observation.
(D) must always be done in the field.

______22. One advantage of recording data accurately is that you can

(A) control the results
(B) repeat the experiment
(C) use the data to prove or disprove your hypothesis.
(D) Avoid having to analyze your data.
.
______23. Before forming a hypothesis, a scientist must first

(A) define a problem.
(B) disprove a theory
(C) collect information
(D) define the variables.

______24. Scientists today learn about the world by

(A) using untested hypotheses to revise theories.

(B) observing, measuring, testing, and explaining ideas.
(C) formulating conclusions without testing them.
(D) changing laws.

______25. A controlled experiment allows the scientist to isolate and test

(A) a conclusion (C) several variables
(B) a mass of information (D) a single variable

______26. Refer to the question below:.

Two science students discovered that the mass of a sample of acetone in an open beaker decreased within a few minutes. One student hypothesized that the acetone reacted with oxygen to form a gaseous compound that escaped. The other student believed that the acetone evaporated into the air. What should the students do to test these hypotheses?

A Combine the hypotheses so they give valid predictions of the acetone's behavior

B Conduct a study of original papers describing the experiments leading to acetone's discovery

C Perform an experiment that attempts to identify the gas above the open beaker

D Ask a classmate's opinion about the chemical and physical properties of acetone

______27. Scientists test a hypothesis by

(A) formulating questions;
(B) designing models;
(C) doing experiments;
(D) drawing conclusions.

______28 During a laboratory activity, a student combined two solutions. In the laboratory report, the student wrote, "A yellow color appeared." The statement represents the student's recorded

(A) conclusion
(B) observation
(C) hypothesis
(D) inference

______29. Mark is studying how heat affects how fast oil flows. He guesses that as the oil gets hotter, it flows faster. How could he test this?

(A) Heat oil to different temperatures. Then weigh it after it flows out of the can.
(B) Observe how fast oil at different temperatures flows down a smooth surface.
(C) Let oil flow down smooth surfaces at different angles. Observe its speed.]
(D) Measure the time it takes for oil of different thicknesses to pour out of the can

_______30 Jim thinks that the more air pressure in a ball, the higher it will bounce. He collects some balls and an air pump with a pressure gauge. How should Jim test this?

(A) Bounce balls with different amounts of force from the same height.
(B) Bounce balls having different air pressures from the same height.
(C) Bounce balls having the same air pressure at different angles from the floor.
(d) Bounce balls having the same amount of air pressure from different heights.

______31. Tom wanted to test how effective dishwashing liquids were. Which of the following is the BEST question for Tom to ask?

(A) What color are the dishwashing liquids?
(B) Which dishwashing liquid is better?
(C) Which dishwashing liquid washes dishes cleaner?
(D) Which dishwashing liquid is oldest?

______32. John wonders what affects the time it takes ice cubes to melt. He decides to test whether the shape of an ice cube affects the time it takes to melt. How could he test this?
(A) Use 5 ice cubes. All should have a different shape and weight. Use 5 identical jars, all at the same temperature. Observe the melting time of the ice cubes.
(B) Use 5 ice cubes. All should have the same shape, but different weights. Use 5 identical jars, all at the same temperature. Observe the melting time of the ice cubes.
(C) Use 5 ice cubes. All should have the same weight, but a different shape. Use 5 identical jars, all at the same temperature. Observe the melting time of the ice cubes.
(D) Use 5 ice cubes. All should have the same weight, but a different shape. Use 5 identical jars, each at a different temperature. Observe the melting time of the ice cubes.

_______33 Some students are studying vitamins. They want to do an experiment. Which is the best question for them to do an experiment with?

(A) Does vitamin A or C dissolve faster?
(B) Why do vitamins dissolve in water?
(C) How do vitamins work in humans?
(D) Does vitamin C prevent a cold?

______34. Some students wanted to do a scientific experiment. Which question below could they most easily try to answer through an experiment?

(A) Why do magnets work?
(B) Why do plants grow most during the summer?
(C) What factors affect plant growth during the year?
(D) What is the affect of different amounts of water on plant growth?

_______35. Tom wants to test this hypothesis: “The hotter the water, the faster sugar will dissolve.” Which would be the best plan to test this?

(A) Set up 4 jars of water. Have #1 at 20^{0}C, #2 at 40^{0}C, #3 at 60^{0}C, and #4 at 80^{0}C. Use one teaspoon of sugar in each jar. Time the dissolving.
(B) Set up 2 jars of water. Have # 1 at 20^{0}C, #2 at 30^{0}C. Use one teaspoon of sugar in each jar. Time the dissolving.
(C) Set up 3 jars of water all at the same temperature. Put one teaspoon of sugar in each jar. Heat jar #1 over low heat. Heat jar #2 over high heat. Do not heat jar #3. Time each one until the sugar dissolves.
(D) Set up 4 jars of water. In jar #1, put 1 teaspoon of sugar. In jar #2, put two teaspoons of sugar. In jar #3, put three teaspoons of sugar. In jar #4, put four teaspoons of sugar. Time all 4 until the sugar has dissolved.

Appendix C: Energy and Work Assessment

Energy and Work Pre & Post Test

Multiple Choice
Identify the letter of the choice that best completes the statement or answers the question.

____ 1. In which of the following is no work done?
a. climbing stairs
b. lifting a book
c. pushing a shopping cart
d. none of the above

____ 2. A force acting on an object does no work if
a. a machine is used to move the object.
b. the force is not in the direction of the object's motion.
c. the force is greater than the force of friction.
d. the object accelerates.

____ 3. What is the unit of work?
a. joule
b. newton/meter
c. watt
d. all of the above

____ 4. If you exert a force of 10.0 N to lift a box a distance of 0.9 m, how much work do you do?
a. 0.1 J
b. 9.0 J
c. 10.9 J
d. 90.0 J

____ 5. If you perform 40 joules of work lifting a 10-N box from the floor to a shelf, how high is the shelf?
a. 0.3 m
b. 20 m
c. 4.0 m
d. 400 m

____ 6. Work is a transfer of
a. energy.
b. force.
c. mass.
d. motion.

____ 7. What is transferred by a force moving an object through a distance?
a. force
b. mass
c. motion
d. energy

____ 8. The energy of motion is called
a. kinetic energy.
b. potential energy.
c. thermal energy.
d. work.

____ 9. A small 20-kilogram canoe is floating downriver at a speed of 2 m/s. What is the canoe's kinetic energy?

a. 22 J
b. 40 J
c. 80 J
d. 400 J

____ 10. A 13-kg sled is moving at a speed of 3.0 m/s. At which of the following speeds will the sled have twice as much kinetic energy?

a. 1.5 m/s
b. 4.2 m/s
c. 6 m/s
d. 9 m/s

____ 11. An object's gravitational potential energy is NOT directly related to which of the following?

a. its height relative to a reference level
b. its mass
c. its speed
d. the acceleration due to gravity

____ 12. Why is the gravitational potential energy of an object 1 meter above the moon's surface less than its potential energy 1 meter above Earth's surface?

a. The object's mass is less on the moon.
b. The object's weight is more on the moon.
c. The object's acceleration due to gravity is less on the moon.
d. both a and c

____ 13. A 4-kilogram cat is resting on top of a bookshelf that is 3 meters high. What is the cat's gravitational potential energy relative to the floor if the acceleration due to gravity is 9.8 m/s^2?

a. 7 J
b. 12 J
c. 29 J
d. 118 J

____ 14. The gravitational potential energy of an object is always measured relative to the

a. location where the object's kinetic energy is zero.
b. position of maximum mechanical energy.
c. reference level from which the height is measured.
d. surface of Earth.

____ 15. The energy stored in gasoline is

a. chemical energy.
b. electromagnetic energy.
c. mechanical energy.
d. nuclear energy.

____ 16. The total potential and kinetic energy of all the microscopic particles in an object make up its

a. chemical energy.
b. electric energy.
c. nuclear energy.
d. thermal energy.

____ 17. Walking converts what type of energy into mechanical energy?

a. chemical
b. electromagnetic
c. nuclear
d. thermal

____ 18. Which of the following statements is true according to the law of conservation of energy?

a. Energy cannot be created.
b. Energy cannot be destroyed.
c. Energy can be converted from one form to another.
d. all of the above

____ 19. If no friction acts on a diver during a dive, then which of the following statements is true?

a. The total mechanical energy of the system increases.
b. Potential energy can be converted into kinetic energy but not vice versa.
c. $(KE + PE)_{beginning} = (KE + PE)_{end}$
d. all of the above

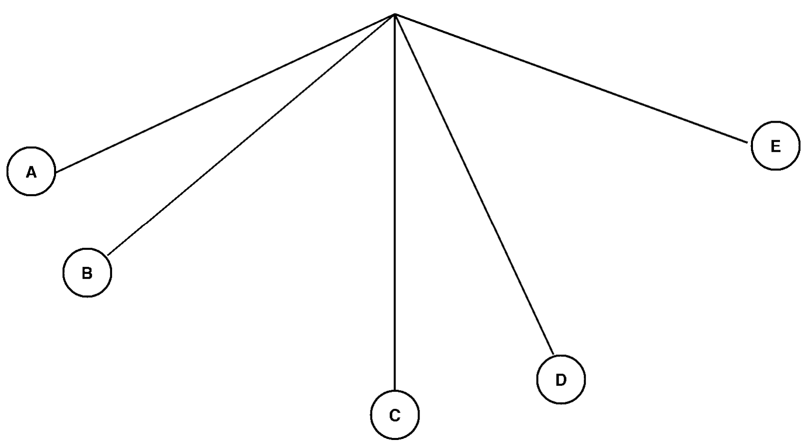

Figure 15-1

____ 20. The kinetic energy of the pendulum bob in Figure 15-1 increases the most between locations

a. A and B.
b. A and C.
c. B and D.
d. C and D.

Appendix D: Pre and Post Assessment for Electricity

Electricity Pre and Post Test

Multiple Choice

Identify the letter of the choice that best completes the statement or answers the question.

____ 1. What do electric forces between charges depend on?

a. the quantity of charge involved
b. how far apart the charges are.
c. both a and b
d. none of the above

____ 2. Walking across a carpet is an example of charge being transferred by

a. contact.
b. induction.
c. static electricity.
d. friction.

____ 3. If a neutral metal comb is held near an object with a negative charge, the comb will become charged by

a. induction.
b. contact.
c. friction.
d. static discharge.

____ 4. What type of current is produced by a battery?

a. parallel current
b. alternating current
c. direct current
d. potential current

____ 5. The type of current in your school is mostly

a. direct current.
b. alternating current.
c. series current.
d. produced by batteries.

____ 6. Which of the following materials allows charges to flow easily?

a. glass
b. wood
c. an electrical conductor
d. an electrical insulator

____ 7. An electrical insulator has

a. electrons that freely move.
b. more protons than electrons.
c. negatively charged ions.
d. electrons tightly bound to its atoms.

____ 8. Resistance is affected by a material’s

a. thickness.
b. length.
c. temperature.
d. all of the above

____ 9. Which of the following would reduce the resistance of a metal wire?

a. increasing its thickness
b. increasing its temperature
c. increasing its length
d. all of the above

____ 10. What is the difference in electrical potential energy between two places in an electric field?

a. current
b. resistance
c. voltage
d. induction

____ 11. Which of the following is maintained across the terminals of a battery?

a. a potential difference
b. a voltage drop
c. an electric charge
d. both A and B

____ 12. The current in a hair dryer measures 15.0 amps. The resistance of the hair dryer is 8 ohms. What is the voltage?

a. 120 V
b. 0.5 V
c. 7 V
d. 1800 V

____ 13. Which of the following represents Ohm’s law?

a. $I = V \times R$
b. $V = I \times R$
c. $R = V \times I$
d. $V = I \div R$

____ 14. How many paths through which charge can flow would be shown in a circuit diagram of a series circuit?

a. one
b. two or more
c. none
d. more information is needed

____ 15. Most of the circuits in your home are

a. series circuits.
b. parallel circuits.
c. reversible circuits.
d. closed circuits.

____ 16. What is the unit of electric power?

a. ampere
b. volt
c. watt
d. ohm

____ 17. If you know the power rating of an appliance and the voltage of the line it is attached to, you can calculate the current the appliance uses by

a. multiplying the voltage by the power.
b. subtracting the power from the voltage.
c. dividing the voltage by the power.
d. dividing the power by the voltage.

____ 18. Which of the following provides electrical safety?

a. circuit breaker
b. fuse
c. ground-fault circuit interrupter
d. all of the above

____ 19. A ground-fault circuit interrupter shuts down a circuit if it

a. melts.
b. senses an overload.
c. senses unequal currents.
d. senses moisture.

Appendix E: Open ended Inquiry Lab of Energy

ENERGY and WORK LAB

In this lab, you will be investigating how our measurable values (kinetic, potential and work) are related to the motion of a marble down a ramp.

You will be working in groups and each person will have to write there own lab report. I have enough equipment for six groups total. You can have groups of 3 or 4. You will work in groups by the questions we create.

PROBLEM (your group must create a question)
Manipulated
Responding
Control

HYPOTHESIS
You must answer the question before you begin.
PROCEDURE:
You must write a procedure. You must also have several circuit diagrams for your procedure. Also you will need three trials!!!!
DATA:
The data table you create must be something that contains both of you variables
ALL OF THE ABOVE MUST BE APPROVED BY ME BEFORE YOU CONTINUE. INCLUDE THIS SHEET WITH MY SIGNATURE IN YOUR FINAL REPORT!!!

ANALYSIS GRAPH:

You will make a line graph that compares your two variables.

ANAYLISIS QUESTIONS: (use complete sentences to answer these questions)

1. What was the hardest part about this lab? Explain.
2. How does this apply to your life in any way? BE SPECIFIC
3. How would you rate the other people in your group in term of there effort and participation. Why?
   (Rate 1 being the lowest and 5 being the best)

CONCLUSION:
Accept or reject your hypothesis and then give data from the lab to back up your acceptance or rejection.

SUGGESTION FOR IMPROVEMENT:
Remember these needs to be about the procedure

Appendix F: Inquiry Electricity Lab

ELECTRICITY LAB

In this lab, you will be investigating how to our measurable values (amperage, voltage resistance, power) are affected by the component of the circuit and how those components are connected.

You will be working in groups and each person will have to write there own lab report. I have enough equipment for six groups total. You can have groups of 3 or 4. You will work in groups by the questions we create.

PROBLEM (your group must choose a question)
INDEPENDENT (MANIPULATED)
DEPENDENT (RESPONDING)
HYPOTHESIS
You must answer the question before you begin.
PROCEDURE:
You must write a procedure. You must also have several circuit diagrams for your procedure. Also you will need three trials!!!!
MATERIALS:
Include how many light bulbs, power sources, wires and measuring tools *(Volts (orange)) Amps (silver)*
DATA:
The data table you create must be something that contains both of you variables
ALL OF THE ABOVE MUST BE APPROVED BY ME BEFORE YOU CONTINUE. INCLUDE THIS SHEET WITH MY SIGNATURE IN YOUR FINAL REPORT!!!

ANALYSIS GRAPH:

You will make a line graph that compares your two variables.

ANAYLISIS QUESTIONS: (use complete sentences to answer these questions)

4. What was the hardest part about this lab? Explain.
5. How does this apply to your life in any way? BE SPECIFIC
6. How would you rate the other people in your group in term of there effort and participation. Why?
   (Rate 1 being the lowest and 5 being the best)

CONCLUSION:
Accept or reject your hypothesis and then give data from the lab to back up your acceptance or rejection.

SUGGESTION FOR IMPROVEMENT:
Remember these needs to be about the procedure.

Appendix G: Traditional "Cookbook" Energy Lab

Name:_____________________________________Date:________________________
Hour :_____________________________________Partners:______________________

Energy and Work Lab

Problem: How does the mass of an object and the height of the object off the ground effect the energy?

Materials: 2 balls the same size but different masses
Meter stick(s)
Balance
Stop watch
3 pieces of wood

Procedure:

1. Weigh each ball on the balance to determine the mass in grams. Record.
2. Place one block under the end of the meter stick ramp. Mark a spot(with tape) on the ramp were you will always release the ball. Now, measure the height of that spot (cm)off the floor .
3. Place one ball at the starting line. Release the ball. Start the stopwatch once the ball reaches the floor.
4. Make sure the ball rolls into the Dixie cup that is placed at the bottom of the ramp.
5. When the ball has used all of it's energy and has come to a stop, record the time and measure the distance from the ramp in meters. Do this three times and find the average time and distance.
6. Repeat step 4 with the other ball.
7. Now add one more blocks of wood and again record the height of the starting point. Repeat step 2-4.

Data: *Note: If I see data exactly the same and you are not in the same group you will receive a zero on this lab!!!!!*

Ball # 1 :
description ____
mass:________g mass :_________kg weight: _________N
Ball # 2 :
description____
mass:________g mass: ________kg weight: _________ N

ONE BLOCK UNDER RAMP (show work for GPE & KE)

	Height (cm)	Height (m)	Distance (m)	Time (sec)	Speed (m/s)	GPE (J)	KE(J)	Work (J)
BALL #1 (1)								
(2)								
(3)								
Average								
BALL #2 (1)								
(2)								
(3)								
Average								

TWO BLOCKS UNDER RAMP (show work for GPE & KE)

	Height (cm)	Height (m)	Distance (m)	Time (sec)	Speed (m/s)	GPE (J)	KE(J)	Work (J)
BALL #1 (1)								
(2)								
(3)								
Average								
BALL #2 (1)								
(2)								
(3)								
Average								

Analysis Questions: *Answer in complete sentences!!!*

1. When in this investigation did each ball have the most potential energy?
2. When did each ball have the most kinetic energy?
3. Why did the ball lose kinetic energy?
4. What is the relationship between mass and energy?
5. What is the relationship between height and energy?
6. Why is it harder to stop a four person bobsled than a three person?
7. What do you notice about the amount of KE and GPE? Are the numbers closes to each other? If not, why?

Conclusion:

Suggestion for improvement:

Appendix H: Traditional "Cookbook" Lab for Electricity

Your Name:______________________________ Group Members:___________________________

Circuits Lab

ANSWER ALL QUESTIONS IN COMPLETE SENTENCES AND SHOW WORK**!!!**

Series Circuits

1. Measure the voltage of each battery using a voltmeter..

Battery 1 __________

Battery 2 __________

Battery 3 __________

2. Connect the negative terminal of battery 1 to the positive of battery 2. Measure the voltage of this combination by touching the positive terminal of battery 1 and the negative terminal of battery 2.

Voltage ____________

What is the relationship of this voltage to the voltages of the individual batteries?

3. Now connect the negative terminal of battery 2 to the positive of battery 3. Leave the first two batteries connected. Measure the voltage of this combination by touching the positive terminal of battery 1 and the negative terminal of battery 3.

Voltage ___________

What is the relationship of this voltage to the voltages of the individual batteries?

4. Connect battery 1 to bulb 1 by connecting the positive end of the battery to the bulb. Now connect the other end of the bulb to the negative end of the battery. Does the bulb light up? __________

Draw a circuit diagram.

Measure the voltage across the battery here.______________________________

Measure the voltage across the light bulb________________________________

Measure the current by placing the ammeter in the circuit before the light bulb

____

Using ohm's law, What is the resistance of this circuit? SHOW WORK!!!

5. Make a series combination of batteries 1 and 2 and connect to bulb 1. Does the bulb light up? ___________

How bright is the bulb compared to the bulb in #4?

Draw a circuit diagram.

Measure the voltage across the battery here.______________________________
Measure the voltage across the light bulb________________________________
Measure the current by placing the ammeter in the circuit before the light bulb
____

Using ohm's law, What is the resistance of this circuit? SHOW WORK!!!

6. Make a series combination of bulbs 1 and 2 and connect to the series combination of batteries 1 and 2. Does the bulb light up? ____________

How bright is the bulb compared to situation #7 & #8

Draw a circuit diagram.

Measure the voltage across the battery here.______________________________
Measure the voltage across the light bulb________________________________
Measure the current by placing the ammeter in the circuit before the light bulb
____

Using ohm's law, What is the resistance of this circuit? SHOW WORK!!!

7. Make a series combination of bulbs 1 , 2, and 3 connect to the series combination of batteries 1 and 2. Does the bulb light up? ____________

How bright is the bulb compared to situation #4 & #5 &#6
Draw a circuit diagram.

Measure the voltage across the battery here.______________________________
Measure the voltage across the light bulb________________________________
Measure the current by placing the ammeter in the circuit before the light bulb
____

Using ohm's law, What is the resistance of this circuit? SHOW WORK!!!

8. What really causes the bulbs to give off light? (voltage, resistance, current)

Power in a Light bulb

9. Construct a parallel circuit with your 3 light bulbs, two batteries in series and a switch.

10. Draw a circuit diagram here.

11. Find the voltage across each light bulb in the parallel circuit

    Bulb 1________________
    Bulb 2________________
    Bulb 3________________

12. Place the ammeter in the circuit and record the current going into each light bulb.
    Current before bulb 1_____________________
    Current before bulb 2_____________________
    Current before bulb 3_____________________

13. Use the current and the voltage to determine the resistance of each bulb. SHOW WORK!!

14. How does that compare to the resistance for each bulb in a series circuit with 3 bulbs and two batteries?

15. Use the power equations to determine the power of each of your light bulbs in parallel. Show work.
    Power Bulb 1_____________________________
    Power Bulb 2_____________________________
    Power Bulb 3_____________________________

Appendix I: Raw percentage scores for each student in each group

Group 1

Pre Inquiry	Pre Energy	Mid Inquiry	Post Energy	Pre Electr.	Post Electr.	Post Inquiry
%	%	%	%	%	%	%
68.6%	19.0%	71.4%	61.9%	25.7%	63.2%	74.3%
45.7%	42.9%	34.3%	42.9%	25.7%	84.2%	37.1%
42.9%	14.3%	17.1%	57.1%	22.9%	42.1%	37.1%
62.9%	19.0%	65.7%	33.3%	25.7%	52.6%	71.4%
74.3%	52.4%	65.7%	66.7%	22.9%	63.2%	74.3%
57.1%	33.3%	65.7%	61.9%	28.6%	73.7%	48.6%
40.0%	23.8%	37.1%	38.1%	25.7%	47.4%	54.3%
45.7%	28.6%	62.9%	42.9%	25.7%	42.1%	62.9%
74.3%	38.1%	82.9%	42.9%	25.7%	52.6%	80.0%
28.6%	38.1%	31.4%	61.9%	17.1%	42.1%	34.3%
65.7%	33.3%	74.3%	52.4%	22.9%	42.1%	45.7%
68.6%	42.9%	42.9%	52.4%	17.1%	68.4%	37.1%
68.6%	57.1%	82.9%	90.5%	28.6%	84.2%	82.9%
68.6%	38.1%	54.3%	47.6%	47.4%	57.9%	31.4%

Group 2

Pre Inquiry MC	Pre Energy MC	Mid Inquiry MC	Post Energy MC	Pre Electr. MC	Post Electr. MC	Post Inquiry MC
%	%	%	%	%	%	%
74.3%	10.0%	80.0%	55.0%	33.3%	63.2%	85.7%
31.4%	65.0%	77.1%	80.0%	75.0%	73.7%	57.1%
65.7%	45.0%	65.7%	75.0%	78.9%	84.2%	68.6%
57.1%	50.0%	68.6%	75.0%	66.7%	63.2%	77.1%
40.0%	20.0%	37.1%	65.0%	66.7%	47.4%	37.1%
65.7%	20.0%	65.7%	45.0%	58.3%	47.4%	51.4%
68.6%	30.0%	82.9%	60.0%	50.0%	73.7%	85.7%
45.7%	40.0%	60.0%	70.0%	50.0%	78.9%	74.3%
65.7%	25.0%	77.1%	55.0%	58.3%	73.7%	82.9%
65.7%	25.0%	82.9%	75.0%	50.0%	89.5%	88.6%
42.9%	20.0%	65.7%	55.0%	50.0%	57.9%	51.4%
17.1%	50.0%	85.7%	100.0%	83.3%	73.7%	82.9%
42.9%	25.0%	22.9%	40.0%	83.3%	68.4%	71.4%
71.4%	65.0%	82.9%	70.0%	68.4%	57.9%	88.6%
54.3%	55.0%	54.3%	80.0%	66.7%	73.7%	65.7%
37.1%	25.0%	42.9%	35.0%	58.3%	63.2%	65.7%

Group 3

Pre Inquiry MC	Pre Enery MC	Mid Inquriy MC	Post Energy MC	Pre Electr. MC	Post Electr. MC	Post Inquiry MC
%	%	%	%	%	%	%
31.4%	50.0%	65.7%	55.0%	36.8%	73.7%	77.1%
57.1%	10.0%	28.6%	5.0%	47.4%	68.4%	65.7%
82.9%	60.0%	82.9%	55.0%	68.4%	68.4%	80.0%
40.0%	40.0%	42.9%	75.0%	36.8%	68.4%	54.3%
71.4%	35.0%	71.4%	60.0%	15.8%	57.9%	77.1%
80.0%	45.0%	82.9%	60.0%	42.1%	57.9%	88.6%
3.0%	15.0%	42.9%	20.0%	15.8%	26.3%	28.6%
20.0%	25.0%	28.6%	60.0%	52.6%	36.8%	60.0%
71.4%	45.0%	80.0%	70.0%	42.1%	52.6%	74.3%
22.9%	45.0%	45.7%	60.0%	31.6%	68.4%	65.7%
45.7%	0.0%	40.0%	45.0%	68.4%	57.9%	45.7%
34.3%	55.0%	60.0%	65.0%	63.2%	68.4%	60.0%
31.4%	45.0%	57.1%	55.0%	42.1%	47.4%	42.9%
22.9%	30.0%	48.6%	65.0%	52.6%	68.4%	45.7%