

THE IMPACT OF INQUIRY LEARNING ON STUDENTS'
ABILITY TO ANALYZE DATA AND
DRAW CONCLUSIONS

by

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ABSTRACT

Previous research suggests that involving students in real world inquiry projects improves their understanding of science content. Some particular features that inquiry teachers use include being a facilitator, modeling inquiry, encouraging student thinking, and engaging students in self-directed learning in which students solve problems, hypothesize, interpret data, create experiments, and explain findings. The primary focus of this study was to determine the impact of inquiry learning on sixth grade students' ability to analyze science data and draw conclusions. The 5E's inquiry teaching model was used during the research. The 5E's include engage, explore, explain, elaborate and evaluate. They are a series of steps when lesson planning that involves creating excitement, asking questions and designing ways to answer questions, sharing information and then taking investigations a step further or to the next level. Activities that were appropriate for Earth Science were selected. Each successive inquiry activity utilized a gradual release of inquiry components. The outcomes of a five week inquiry unit were compared to the results of a five week traditional teaching unit. The results of this study suggested both traditional and inquiry teaching are important to develop well-rounded science students. Inquiry teaching improves students' ability to apply science skills to data and analysis and drawing conclusions tasks. This produces strong science thinkers. Traditional teaching improves students' ability to demonstrate data analysis and drawing conclusions skills on traditional tests. Because students need all of these skills, both teaching methods should continue to be an integral part of teaching.

INTRODUCTION AND BACKGROUND

In my classroom I have found that students struggle with data analysis and drawing conclusions. This seems to be especially true when they are working with data and numbers that they don't find meaningful. When students are presented with data tables or graphs from an outside source that they have difficulties relating to, they don't seem motivated to explore and to draw valid conclusions about the data. Students seem more motivated when they have been involved in asking the questions or collecting the data. I can make scientific data and numbers more meaningful to students by involving them in inquiry tasks that require them to take ownership of the science lab or activity. I've learned that although utilizing an inquiry teaching method during lab type activities is an important step to developing young science minds, it is not in itself enough. I must also strive to teach students to think like scientists by having them analyze how the results of theirs and others research and data impact science knowledge and understanding. I need to teach them what inquiry is and means. I feel like discussions about data analysis and drawing conclusions could be a great way to do this.

This study is significant to my classroom because, The Next Generation Science Standards (NGSS) lists Analyzing and Interpreting Data and Constructing Explanations as Science and Engineering Practices that all students need to master. It is important for me to find effective methods for teaching data analysis and drawing conclusions.

Students in Wisconsin will continue to take the Wisconsin Knowledge and Concepts Exam (WKCE) as a state-wide standardized test in the science area. This test focuses largely on data analysis and drawing conclusions. Students are often asked to use

general science background knowledge and apply it to analyze and draw conclusions about data from tables, charts, graphs and diagrams. In addition to Analyzing and Interpreting Data and Constructing Explanations, the NGSS also lists six other Science and Engineering Practices that are necessary for students. Several of these practices such as Asking Questions and Defining Problems, Developing and Using Models, and Planning and Carrying Out Investigations are inherent in the inquiry process. By using inquiry to teach data analysis and drawing conclusions I feel that I am preparing students for high stakes testing and they are learning the Science Practices from The NGSS. My classroom experiences have led me to the question, how can I improve students' ability to analyze data and draw conclusions?

My primary research question is “What is the impact of an inquiry-based unit which emphasizes data analysis and drawing conclusions in a 6th grade Earth Science classroom?” The following are sub-questions:

1. How does the outcome of inquiry as a teaching method for data analysis and drawing conclusions compare to the outcome of more traditional teaching methods for data analysis and drawing conclusions?
2. How do students react to inquiry learning (confidence, engagement, and motivation?)
3. How does inquiry teaching affect the teacher?

My support team included Val Williams, Karl Ascher, Tom Rheinheimer, and Kristin Heller. Val is another teacher on my sixth grade team. She is the math teacher so she also does significant teaching of data analysis and drawing conclusions based on data. Val and I will be collaborating to write a proposal for a new STEM class for our sixth

grade students next year. Karl is the eighth grade science teacher at Parkside where I teach. He has been teaching for many years and has had many great insights from a science perspective. Tom was the principal at Parkside. Tom is a very data driven person. A lot of our past school decisions were made based on the numbers. He is also a very goal driven individual. Tom has recently moved to the high school and is the principal there. Deb Premo is the new principal at Parkside. I have looked to her for input and support also. Kristin is my wife and a fellow teacher. She is a language arts teacher and she has had valuable advice about the written portion of my final project. I have selected these people because they are the ones that I find myself naturally going to when I when I need advice or just to talk about something at school. They are all very supportive in nature, yet have been able to provide me with constructive feedback in a positive way so that I can continually improve my project.

CONCEPTUAL FRAMEWORK

Research Studies

In a research study of 94 tenth grade science students Tarirab and Khalaf Al-Naqbi (2003) found that students struggle more during qualitative analysis (finding trends) than quantitative reading (reading points and identifying values) of graphs. The authors suggested that a possible reason for this was that students are more frequently asked to work with graphs quantitatively than qualitatively. The researchers then consulted commonly used textbooks to confirm this. I included both quantitative and qualitative analysis practice in my action research study, specifically focusing instruction on finding trends qualitatively.

In addition, Tarirab and Khalaf Al-Naqbi (2003) interviewed students to find strategies that students used to interpret and construct graphs. Their interview results revealed that students' performance were sometimes hindered by their inability to correctly identify the types of graphs they were interpreting. In my action research students were exposed to a variety of types of graphs and tables.

In a study of 59 inner city sixth grade students, Lee and Butler (2003) found that involving students in real world inquiry projects improves their understanding of science content when three important criteria have been met. The first is that the inquiry project matches student's content knowledge and past activities. The second condition is that content knowledge is taught while real science thinking is taking place. The final criterion is that students need guidance in order to meet both the content and inquiry goals. I focused my action research inquiry methods on real world situations that relate to students' background and growing knowledge.

Bilbrey and Taylor (2012) conducted a study in a rural Alabama school with 1,210 students about the impact of inquiry on fifth grade science students. The study measured state test scores of fifth grade students for three years with traditional teaching methods. Then compared it to three years with inquiry teaching methods. The school used a method known as the Alabama Mathematics, Science, and Technology Initiative. These methods include extensive professional development for teachers along with the implementation of inquiry based learning units and necessary supplies. Researchers found no significant impact from inquiry on the fifth grade group as a whole. However when completing further analysis the study found significant impact for certain

subgroups. The subgroups who showed significant growth during inquiry were male students, students living in poverty, and African American students.

Theoretical Background

According to the Center for Science, Mathematics, and Engineering Education (2000), inquiry standards were described as including both abilities and understandings. The National Science Education Standards include both Fundamental Abilities Necessary to do Scientific Inquiry and Fundamental Understandings about Scientific Inquiry.

Reforms were made to shift from inquiry as simply a set of skills to inquiry as both skills and an understanding of inquiry. It doesn't appear that this shift has been carried out in classrooms (Abd-El-Khalick et al 2004). Instead it seems the focus is still on students doing independent inquiries. To stress the importance of understanding inquiry Abd-El-Khalick et al (2004) explain

Indeed, do we expect citizens to execute a scientific investigation every time a decision on a science-related personal or social issue is needed: Of course not, rather our citizens are expected to know enough about science content, inquiry, and the NOS to be able to understand scientific claims and make informed decisions (p. 402).

While studying the effects of inquiry learning on students' ability to analyze and interpret data, I used our data analysis as an opportunity to discuss how scientists look at the work of other scientists and make decisions about the value of the research as well as asking new questions that stem from the results.

Anderson (2002) says that there is not a clear definition of what inquiry teaching is in the research that has been done. “While research says inquiry teaching can produce positive results, it does not, by itself, tell teachers exactly how to do it” (Anderson, 2002, p. 4). Some particular features that inquiry teachers use include being a facilitator, modeling inquiry, encouraging student thinking, and engaging students in self-directed learning in which students solve problems, hypothesize, interpret data, create experiments, and explain findings.

The Center for Science Mathematics, and Engineering (2000) has identified common components in several inquiry based learning models, the basis of which can be traced back to Piaget’s theory of development. The components include a question that creates inconsistency with their thinking and motivates them to learn more, exploration that leads to hypotheses and explanations, data analysis and interpretation that puts their ideas together, extending their learning to new situations, and reflection. I used the 5E’s inquiry teaching model as my treatment method during my action research. The 5E’s include engage, explore, explain, elaborate and evaluate. They are a series of steps when lesson planning that involves creating excitement, asking questions and designing ways to answer questions, sharing information and then taking investigations a step further or to the next level.

Research Methodologies

In her research about the impact of small groups, Moyer (2011) used a data collection matrix to show the 3 data sources she used to evaluate each of her research

questions. I used the matrix tool as I planned for multiple methods of data collection for each of my research sub questions.

Additionally, Moyer (2011) used several graphs to make her data very visual and easy to understand. When recording and reporting observational data, she used a numbering system to match with desirable behavior in order to quantify student behavior. Zero was no data, 1 meant no, 2 was some of the time, 3 meant most of the time, and 4 was all of the time. Both of these strategies made the data accessible and easy to understand. I have used graphs in my action research data analysis to visually display my data. I will also use a numbering system to make my observational data more understandable.

Tarirab and Khalaf Al-Naqbi (2003) provided some valuable information on how to validate questions used in an assessment piece. The authors involved other science teachers to determine which questions should be used in the final assessment tool. In creating my pre and post assessments I sought input from other teachers in my school district.

In his research about the impact of iPads in science education Benson (2013) used a numerically coded Likert scale to assess students' motivation to learn science. I used a similar method to assess students' confidence and motivation relating to data analysis. Benson (2013) also utilized a data triangulation matrix and bar graph to make data easy to follow and comprehend. As I mentioned earlier, these are valuable tools I incorporated into my research project.

METHODOLOGY

Treatment

First, I used a five week unit that incorporated data analysis and drawing conclusions using traditional teaching methods. At this time students were made aware that they were participants in the research I was completing on teaching methods. Then I taught a five week unit that incorporated data analysis and drawing conclusions using an inquiry teaching method. Each unit was the same length in terms of the number of class periods students were engaged in the specific teaching method. I had one science colleague and one math colleague review the units to help ensure that they were of equal difficulty.

The traditional teaching method used was teacher centered instruction. Short lectures were used as a primary mode of instruction. Science labs and activities that were performed were highly structured and guided students step by step through the lab or activity. The topics I covered during this traditional teaching were related to plate tectonics. During the unit, students worked with analyzing data and drawing conclusions in one of two ways. They completed structured lab activities that walked them through each step in the procedure and then analyzed the data and drew conclusions based on the lab. The other type of activity completed was the students worked with data that was given to them by the teacher. Students were asked to analyze the data and draw conclusions from it.

The treatment method I used was the 5E's model for teaching inquiry. The first inquiry activity was solar system argumentation. The second inquiry method involved students exploring the role of gravity in the solar system. The third inquiry project was an investigation of impact cratering. Student instructions for the impact cratering project have been included as Appendix A. I used a gradual release of responsibility method for introducing each of the inquiry projects as my students had limited experience with self-directed inquiry. All students performed all the steps of the 5E's model. However, during the first inquiry project students performed some of the steps as a class and some in small groups. The second project had students complete most of the steps in groups. The last inquiry project had students completing all of the 5E's steps in their groups with the final data analysis and conclusions drawn on their own.

During these 5E's lessons the majority of students' time was spent on the explore, explain, and evaluate steps. The explore step typically took about two 90 minute class periods. This included brainstorming questions, investigating the materials, designing the experiment, and finally carrying out the experiment. The explanation step typically took about one class period. This involved constructing graphs and tables, analyzing data, and drawing conclusions. The evaluation step also took about one class period. This was when students shared their findings. They were required to question their peers and defend their own evidence. Both the engage and extend steps took significantly less time ranging between 15 and 45 minutes. Most of this was done as whole group demonstrations and discussions or small group activities.

The inquiry activities during my treatment method met all the following criteria suggested by Brunsell, Knesser and Niemi (2014):

- Students will identify their own scientifically oriented question.
- The activity will encourage students to seek out additional information, connect to known science, and/ or share results with classmates.
- The activity will engage students in making sense of data by generating an evidence-based explanation to attempt to answer the question.
- The activity will provide an opportunity for students to engage in argumentation from evidence-justifying their explanations and/or critiquing the explanations of others?

Instrumentation and Research Design

Table 1
Data Matrix

Research Question	Data Collection Method1	Data Collection Method 2	Data Collection Method 3
How does the outcome of inquiry as a teaching method for data analysis and drawing conclusions compare to the outcome of more traditional teaching methods for data analysis and drawing conclusions?	Pre and post test questions on data analysis skills.	Pre and post test questions on drawing conclusions skills.	Performance assessment of students' ability to create a graph, analyze data and draw conclusions about the data in the graph.
How do students react to inquiry learning (confidence, engagement, and motivation?)	Observations of time on task.	Likert scale survey of students' confidence and motivation relating to data analysis and drawing conclusions.	Student interviews about confidence, motivation, and engagement relating to data analysis and drawing conclusions.
How does inquiry-based learning impact the teacher?	Teacher journaling.	Likert scale student survey questions about their perception of the teacher.	Student interview questions about their perception of the teacher.

The pre and post test questions were well suited to assess the outcome of inquiry teaching compared to the outcome of more traditional teaching because I compared student growth during an inquiry unit to growth during a traditional unit. The Tables and Graphs Test is included as Appendix B. This quantitative data showed me the impact of inquiry on students' ability to analyze data and draw conclusions. Each of the pretest and post test questions has been assigned a Bloom's Taxonomy level. The rubric used to assess the performance tasks has also been aligned to Bloom's Taxonomy. The Performance Assessment Rubric is included as Appendix C. This allowed me to further analyze if students made gains, stayed the same, or went down in both areas of higher and lower level thinking skills. Using both multiple choice questions on the pretest and posttest as well as assessing student's skills through performance assessments provided me with a picture of how students have grown in both evaluating science data and doing science. In order to help insure validity I had the eighth grade science teacher, the sixth grade math teacher, and the building principal read the test and give me feedback on the value and skill level of each item. I made slight modification to the wording of some questions based on their feedback. In order to help insure reliability I had a group of students that I had last year take the test. These students scored approximately how I predicted they would based on my knowledge of their science ability from last year.

The performance assessment rubric was used to assess students' performance on a skills based learning task. Students completed one performance task, Crustal Sinking, during the non-treatment unit and one performance task, Scale Model of the Solar System, during the treatment unit. The Crustal Sinking Performance Assessment and the

Scale Model of the Solar System are included as Appendix D and E. For each task students constructed a data table and a graph. In addition, students completed three questions. One question required them analyze the information in their graph. A second question required them to synthesize the information from the graph with their background knowledge. The evaluation question required students to take the information from the graph and apply it to a unique scenario. The performance assessments provided quantitative data as I used a rubric to score students skills after the traditional and inquiry units. I also analyzed these qualitatively looking for patterns in the way they supported their findings and areas of strength or weakness. In order to help insure validity and reliability both of these came from the Performance Assessment Links in Science (PALS) resource bank which is a vetted website source.

Additionally, I used time on task observations, Likert surveys, interviews and journaling to gather data about students' confidence, engagement and motivation and the impact on the teacher. I used time on task recording instrument from Dr. Stronge's Educator Effectiveness Project. The Time on Task Recording Chart is included as Appendix F. I chose this tool because it is used by the administrators at my school to observe student engagement when they visit teachers' classrooms. I video recorded ten minute sessions during class. Then for every five minute interval I wrote down the total number of students, the number of students visibly disengaged, and the number of students distracting others. I also recorded the class activity taking place and how disruptions were handled by the teacher. I developed my Likert survey by modifying several questions from the Program in Education, Afterschool and Resiliency (PEAR)

Attitude Towards Science Survey. The Attitudes Towards Science Survey is included as Appendix G. I also added several question to elicit responses about several specific class activities we had done. I created interview questions based on the responses from the Likert survey that I wanted more information about. Interview questions are included as Appendix H. I used journal prompts suggested by a Montana State adjunct professor, Walter Woolbaugh to gather information about the impact of my action research on the teacher.

I taught five sections of sixth grade earth and space science, each with 16-22 students. I implemented my treatment method of using inquiry to teach data analysis and drawing conclusions with all of these students. However, I collected data from just three sections. There was a section of students grouped together because they all receive high math instruction. There was also a group of students that all receive reading and math interventions. In addition, there were three average ability groups. I collected data from one of the average groups, the high math group and the intervention group. I have selected the high math group and the interventions group because I feel it is equally important to challenge our strong students as to provide interventions for our struggling students. I included all students from these three sections (54) in the pre and post test questions, Likert scale surveys and performance assessments. I randomly selected students to do the interviews. The schedule I used to collect my data can be found in the Data Collection Timeline, Appendix I.

Parkside School is a 4th-8th grade building, located in the Wautoma, Wisconsin. Wautoma is a small, very rural community located in the central part of the state.

Parkside School is a Title 1 School with a free and reduced lunch student population of 67%. A Title 1 label is a federal government label given to schools who educate higher numbers of disadvantaged students. Parkside received a Wisconsin School of Promise Award in 2014, in recognition of performing within the top 25% of higher poverty schools.

The three sections of students used in my action research all had different demographics. The higher ability section had eight male and eight female students. This section contained two Hispanic students both who were English Language Learners (ELL) and the rest of the students were Caucasian. The average ability section of students contained 10 males and eight females. This group was comprised of five Hispanic students three which are labeled as ELL, one African American student and 12 Caucasian students. The lower ability learner group was made up of nine male students and ten female students. This section was comprised of eight Hispanic students in which five were labeled as ELL, two African American students and ten Caucasian students. This group contains six students who received special education services. All sections of students have had minimal experience with inquiry learning.

The research methodology for this project received an exemption by Montana State University's Institutional Review Board and compliance for working with human subjects was maintained. A copy of the IRB exemption can be found in Appendix J.

DATA AND ANALYSIS

My primary research question sought to find the impact of an inquiry teaching method on students' ability to analyze data and draw conclusions. In other words, what

would be the results of inquiry teaching on student achievement, motivation, confidence and engagement and how would the teacher be impacted? Figure 1 below represents the baseline, non-treatment and treatment data for the three student groups. The overall results for each class are presented in the figure. Standard deviation for each group of students is shown.

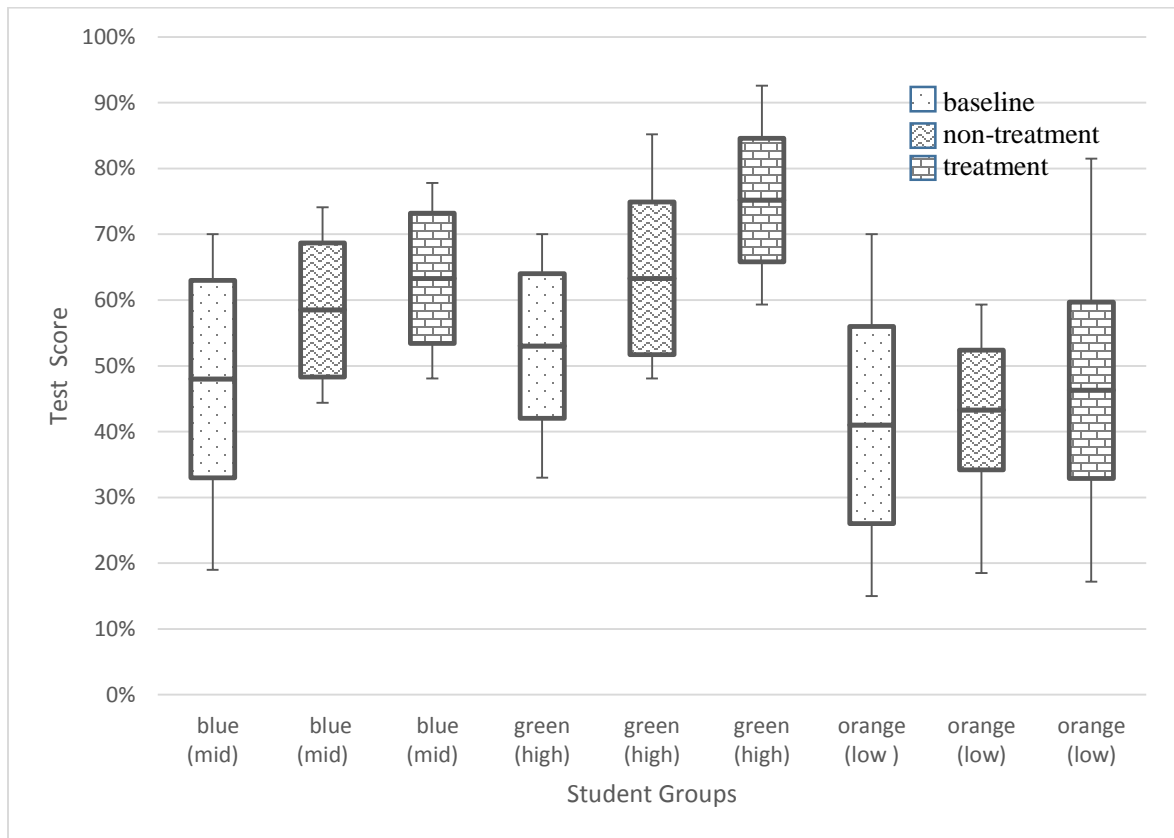


Figure 1. Tables and Graphs Test scores for all student groups, (N=54).

One initial insight according to Figure 1 is that although my students are grouped according to ability, the maximum value for each group is exactly the same for the baseline test. It is somewhat surprising that a student in the low group had a maximum score of 70%. Based on daily performance I would have suspected a significantly lower maximum score. In this group there are several students whose behavior disabilities

often interfere with their academic success, which is why they are placed in this lower achieving group. The maximum score of a 70% was from one of these students with a behavior disability. I believe this student has high academic ability, but their behavior often gets in the way of performing to their ability level. Typically, I see lower scores from this student. This student had a rare good behavior day when they took the baseline test.

Figure 1 also shows baseline data that was more predictable such as the mean values and standard deviations for the groups. The mean for the high group was initially the highest at 53%, followed by the middle group at 48% and then the low group at 43%. The upper group is comprised of higher academically achieving math students therefore I would have expected them to have the highest mean and the smallest standard deviation, which they do. Although the middle group, which is comprised of average achieving students, has a higher mean than the low group, they have a similar standard deviation.

Figure 1 shows some interesting data on student achievement during inquiry. First of all, all student groups showed continual growth during the inquiry unit. The high group showed the largest growth of 12 percentage points. The average group grew five percentage points during inquiry. The low group grew five percentage points.

The standard deviation for all student groups went down from the baseline. The high ability group had the smallest standard deviation during inquiry. It lowered from 2.87 to 2.55. The middle ability group standard deviation went from 3.78 to 2.68. The lower ability group lowered from 3.93 to 3.62. The lower groups' standard deviation was influenced by two major outliers. The maximum outlier was a different student than the

baseline test. This student is not a special education student, but he is an intervention student. Intervention students are students that receive additional math and reading support because of low standardized test scores and teacher recommendations. Based on this student's daily performance, I believe the student got very lucky. The minimum outlier was a student who also receives intervention services. This is a student who has been identified with test anxiety.

Another interesting finding from Figure 1 is that the lower level section of students had a larger standard deviation during inquiry teaching than traditional teaching. This means that as a result of inquiry teaching there is a small sub set of students found at the high end of the standard deviation that scored significantly higher as a result of inquiry teaching. Even though this affects just a small number of students it is significant to find because of the amount of time and money invested in closing the gaps between lower achieving students and their peers.

The results of the Likert surveys offer some insight about students' engagement, confidence and motivation during the inquiry unit. Students were asked to reflect on the activities during each unit as they respond to survey items. At the conclusion of the traditional teaching units 57% (N= 663-676) of student responses to Likert items about confidence, engagement, and motivation were positive compared to 60% positive responses during the inquiry unit. Additionally, from the non-treatment unit to the treatment unit the strongly agree responses moved from 16% to 23%. This indicates that not only did the overall positive responses increase, but that students also felt a stronger amount of confidence, engagement, and/or motivation during the inquiry unit.

Categorical survey results for confidence, motivation, and engagement will be discussed later on.

Table 2
Raw Score Average Growth on Tables and Graphs Test (N=54)

	Total Growth	Analyzing Data	Drawing Conclusion
Non Treatment	2.09	1.54	0.83
Treatment	1.67	0.91	0.57

My first sub question compared the results of inquiry to the results of a traditional or teacher centered science unit. According to Table Two the results from the Tables and Graphs Test showed that students' scores increased by 2.09 points during the traditional teaching unit. During the inquiry unit students' scores increased by 1.67 points. The data analysis type of questions showed students grew 1.54 points during the traditional unit and grew .91 during the inquiry unit. Likewise drawing conclusion type of questions showed that students grew .83 during the traditional unit and only .57 during the inquiry unit. Traditional teaching had a larger impact on student achievement than inquiry on students' ability to answer traditional data analysis and drawing conclusion test questions. I think this is because the traditional teaching activities are well structured to prepare students for traditional multiple choice test questions. The highly structured nature of traditional teaching matches the highly structured nature of objective test questions.

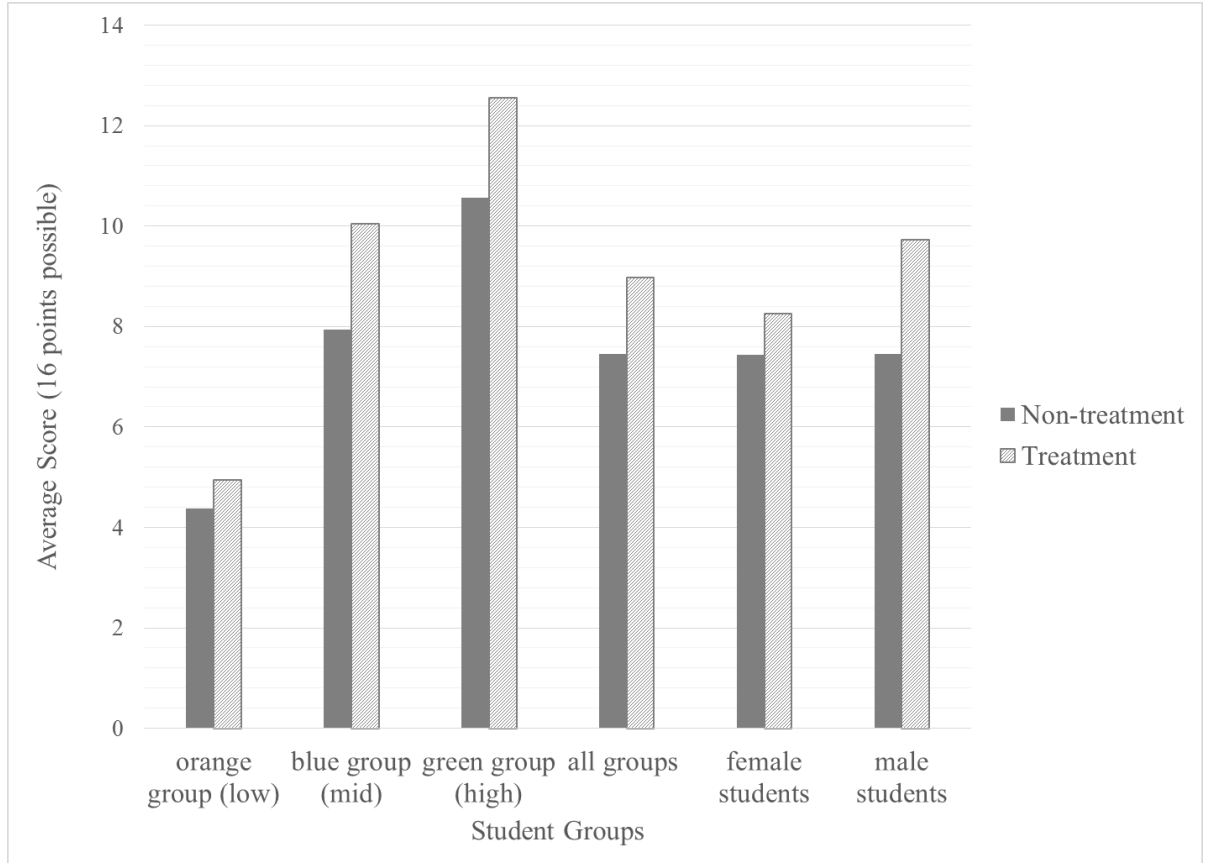


Figure 2. Performance task average raw scores, ($N=54$).

Although overall growth on the Tables and Graphs Test does not indicate an advantage to inquiry teaching a further analysis of sub groupings supports the use of inquiry with certain groups of students. On the Tables and Graphs Test the higher level students achieved more growth during the inquiry unit. During inquiry the higher ability group, with students selected for stronger math skills, grew an average of 3.21 points on the test compared to only 2.5 during the traditional unit. By contrast, students in the middle ability group grew 3.28 points during the traditional unit compared to only 1.33 points during the inquiry unit. The lower ability group had virtually the same growth for both the non-treatment and treatment units at .7 points and .75 points respectively.

When comparing student growth in the area of drawing conclusions, students showed more growth, 16.07%, during the inquiry unit than the traditional teaching unit, 8.3 %. In contrast, when comparing student in the area of data analysis, students showed more growth during the traditional teaching unit, 9.07%, than the inquiry unit, 5.36% (see Table 2).

A second instrument used to compare student achievement was performance tasks. The skills included on the performance task included making tables and graphs, analyzing data and drawing conclusions. On these tasks students were asked to look at data they gathered and hypothesize possible explanations for the results. This required them to synthesize the data and their prior science knowledge. These tools were completed by students at the end of the non-treatment and treatment units. According to Figure 2, on the non-treatment performance task students' average score was 7.45. On the treatment performance task the average score was 8.98. Inquiry had a greater impact than traditional teaching on students' ability to use science skills. This is likely because inquiry teaching puts more emphasis on students asking questions and proving them. After the inquiry unit students were more prepared to answer subjective questions about their own data and hypothesize reasonable conclusions.

The results of performance assessments showed the highest impact for average learners with 7.94 the average score on the non-treatment performance task and 10.06 on the treatment performance task (see Figure 2.) The inquiry teaching had a similar result for high learners with 10.56 the non-treatment average and 12.56 the treatment average.

The inquiry unit showed the lowest impact on the below average learners with scores of 4.37 and 4.95 on the traditional and inquiry units respectively.

Additionally, inquiry teaching had a larger impact on males than females. This was evident in both the Tables and Graphs Test and performance tasks. During the inquiry unit males grew 2.70 points versus 1.52 points on the Tables and Graphs Test and performed 2.27 points higher on the inquiry performance task. On the other hand, female students grew only .67 points during inquiry versus 2.67 points during traditional teaching on the Tables and Graphs Test. Female students did perform better on the inquiry performance task, but their score was only .82 points higher than the traditional teaching method performance task score. They were also 1.45 points behind the male average score for the inquiry performance task. Interestingly, female students averaged 7.44 points on the traditional teaching performance task, which was nearly identical to the male score for the same task of 7.46 points. I think the reason for the discrepancy in scores is that boys and girls do not learn in the same way because of their different strengths and weaknesses.

Table 3
Results of Time on Task Observations (N=51-54)

Student Negative Behaviors	Non-Treatment Total	Treatment Total
Blue (mid) Disrupting Others	3	2
Green (high) Disrupting Others	1	0
Orange (low) Disrupting Others	7	6
Total Occurrences of Disruption	11	8
Blue (mid) Visibly Disengaged	10	5
Green (high) Visibly Disengaged	6	4
Orange (low) Visibly Disengaged	18	21
Total Occurrences of Disengagement	34	30

The second sub question I investigated focused on the impact of inquiry teaching on students' engagement, motivation and confidence in my classroom. The first instrument used to measure the impact of inquiry was time on task observations. The results of the observations showed that overall disruptions were more frequent during the non-treatment unit versus the treatment unit by a total of three disruptions, as shown by Table 3. The total number of overall occurrence of students being disengaged was also more frequent during the non-treatment unit compared to the treatment unit by a total of four occurrences.

A closer look at time on task data revealed that the different student groups were impacted differently in the area of class engagement. The average ability group had a drop in disengaged occurrences. They went from ten during the non-treatment to five during the treatment unit. The upper group saw a small drop in disengagement from six occurrences during the non-treatment to only four during the treatment. The lower ability group had much higher levels of disengagement occurrences than the other two groups. They also differed than the other groups because they had an increase in disengagement occurrences from non-treatment to treatment unit. During the non-treatment unit there were 18 occurrences of disengagement and it increased to 21 during the treatment unit. I would attribute this increase during the inquiry unit to students not possessing the needed skills to complete these less structured activities without major guidance from the teacher. The skills and confidence of the low group may limit their ability to be self-guided and self-motivated. Therefore when they believe a problem is beyond their

abilities, they often exhibit disruptive behaviors or become disinterested in what they are supposed to be accomplishing.

The second tool I used to evaluate the impact of inquiry learning on student engagement, motivation and confidence was a Likert Survey. The areas of student engagement, motivation and confidence had several questions on the survey specifically designed to measure each of them. There were four questions on the Likert Survey that measured student engagement. The results of the individual questions were compiled together to display an overall picture of the impact of inquiry on the learner. An example question in the engagement area on the survey was, “During science class, I am usually interested.”

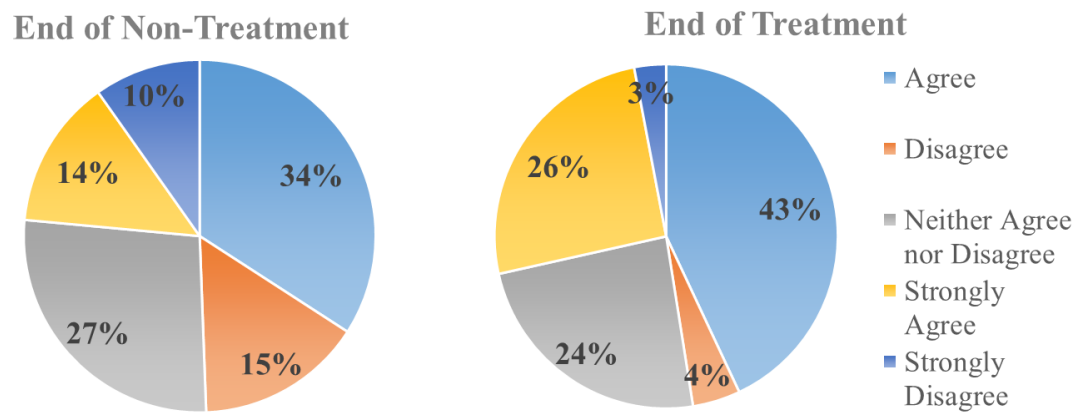


Figure 3. Science Attitudes Survey results for student engagement items, (N=204-208).

The final results of the survey showed that student engagement greatly increased from the non-treatment unit to the treatment unit. As seen in Figure 3, the biggest change from non-treatment to treatment was the “strongly agree” response increased from 14%

to 26%. The next biggest increase from non-treatment to treatment in terms of student engagement was the “agree” response went from 34% to 43%. At the end of the inquiry unit 69% of student responses about engagement in science class were positive, compared to 48% at the end of the traditional unit. There was a large decrease in the number of student responses that showed negative feelings about being engaged in science at the end of the inquiry unit. At the end of the inquiry unit only 7% of student responses showed negative feelings towards being engaged in the science classroom. I believe when students are given choices and freedom during classroom activities they feel more engaged in the learning process.

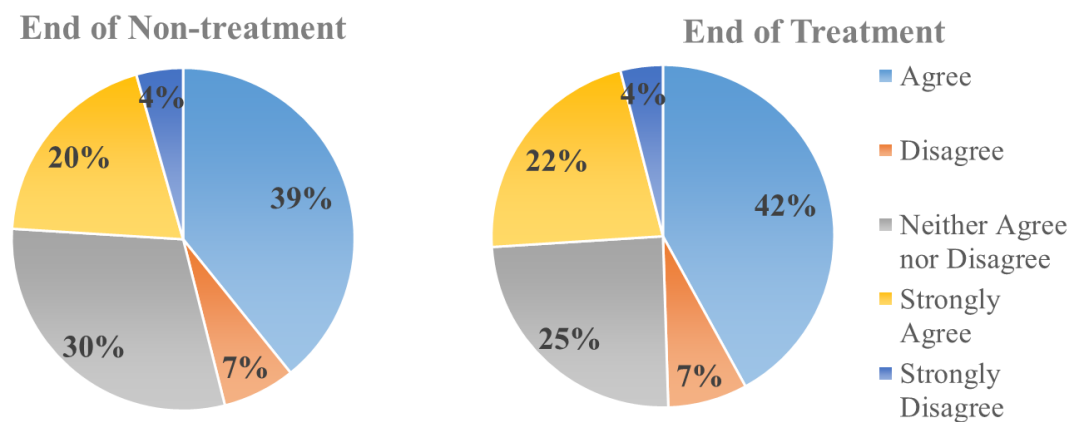


Figure 4. Science Attitudes Survey results for student motivation items, ($N=204-208$).

The second area the survey addressed was student motivation. There were four questions on the survey related to students’ thoughts on motivation in the science classroom. An example question in the motivation category was, “I would like to learn more about science.” Student motivation increased slightly from the non-treatment to treatment unit based on the Likert survey results. Figure 4 shows the “strongly agree”

responses increased from 20% to 22% the “agree” responses increased from 39% to 42%. Overall positive responses increased from 59% to 64%. Negative responses pertaining to motivation were exactly the same in the non-treatment and treatment units. The percent of neutral responses went down from 30% to 25%. I feel when students are authentically engaged in an activity they are motivated to work hard in order to analyze the results and reach conclusions.

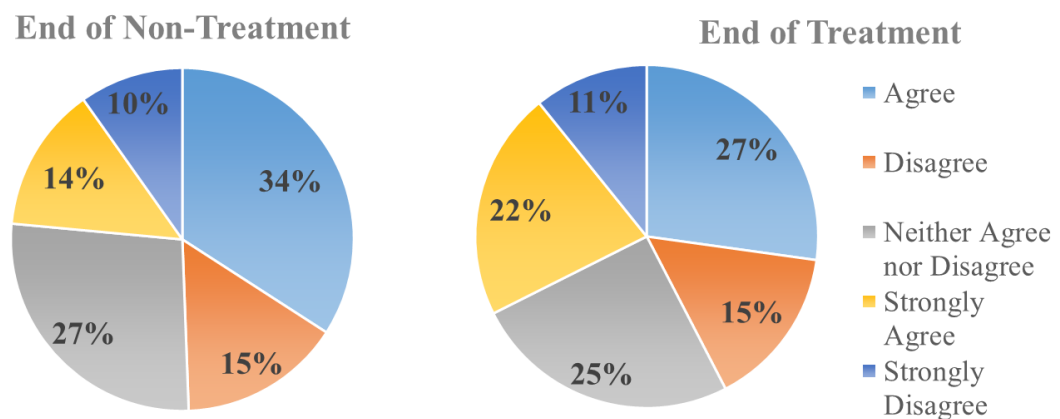


Figure 5. Science Attitudes Survey results for student confidence items, (N=255-260).

A third area the Science Attitude Survey addressed was student confidence in the science classroom. There were five questions on the survey that were related to confidence. Examples of these types of items were, “Science is challenging for me” and “Graphs are difficult for me to understand.” According to Figure 5 the largest change from non-treatment to treatment was in the “strongly agree” response, which increased from 14% to 22% (N=50-54). The number of responses that showed positive feelings about confidence in science was virtually unchanged from non-treatment to treatment unit. Likewise the number of responses that showed negative feelings about confidence

in science was virtually unchanged from non-treatment to treatment. The results demonstrate that learning through inquiry produces questioning. The inherent unknowns of an inquiry activity did not increase confidence in students' science ability. Likewise, it did not lower students' confidence.

Another tool used to assess student's confidence, motivation, and engagement was student interviews. The interviews were conducted with three students from each class at the end of the non-treatment and treatment units. I chose students at random, however, I made sure I had at least one female and male student in each interview group. During each interview students were asked to reflect on the specific activities involved in each unit.

The first theme I found when analyzing the data in regards to student engagement was in response to the question, "In the past five weeks, what was the most exciting thing we did in science class?" During the non-treatment unit students were split in their responses, with four students choosing the CSI activity, followed by two choosing ocean floor mapping, two choosing sinking mountains, and one choosing an iPad mapping activity. By contrast, at the end of the treatment unit eight students picked the impact cratering with only one student choosing the planet activity. This is significant because the impact cratering activity was both the most open ended of the inquiry activities and the most student directed.

Additionally, in response to the follow up to this question, "What did you like about this activity?" students were readily able to list several items they liked after the inquiry unit. Responses included "You got to do it by yourself," "You got to do

whatever you wanted,” “I liked to figure out what went wrong and how to fix it,” “It was fun,” “I liked testing the materials before designing the experiment,” and “It made a huge mess.” After the non-inquiry unit I had to do a lot of probing and still students weren’t able to come up with very many things they liked about the activities. Responses included, “computing the composition,” “manipulating,” “matching the sample numbers,” and “the video about the museum.” The inquiry activities were more memorable to students and left a lasting positive impression.

Additional analysis of the interviews revealed another theme, this time in regards to student confidence. Students were asked to rate their confidence at making, reading and drawing conclusions from science graphs. During the non-treatment unit students rated themselves at an average of 6.33 for making graphs. They rated themselves at an average of 7.33 during the treatment unit. Their confidence in drawing conclusion also increased as a result of the inquiry unit. They rated themselves at an average of 5.28 at the conclusion of the traditional unit compared to 7.44 at the conclusion of the inquiry unit. Students’ confidence in reading graphs declined. During the non-treatment unit students rated themselves at an average of 7.41 compared to 6.61 during the treatment unit. Students’ confidence in reading graphs may have gone down due to the fact that there was less direct instruction in reading graphs during inquiry. During the traditional unit activities, students collected the same data and experienced similar results, which led to entire class instruction of reading graphs. The freedom offered during the inquiry learning led to less of these whole class discussions.

Student motivation was a third area where a theme became obvious from the interviews. The question students responded to was, “What activities made you curious or want to know more in the last 5 weeks?” In student responses during the non-treatment unit, students stated an activity but even with further probing were not able to articulate something they wanted to learn more about. During the inquiry unit students showed genuine motivation by stating a clear idea that they wanted to learn more about. Examples of student responses were, “I want to learn what other planets exist,” “I want to know more about objects further out in space,” and “I want to try to run someone else’s experiment.”

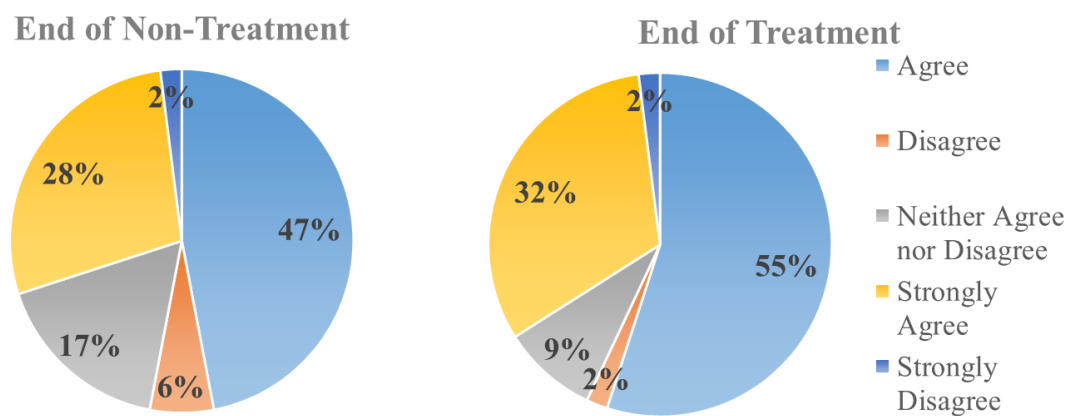


Figure 6. Science Attitudes Survey results for impact on the teacher, ($N=51-54$).

The third sub question was about how inquiry teaching affects the teacher. The first instrument I used to measure this was a question on the Science Attitude Survey. The survey item was “Mr. Heller enjoys teaching science.” Figure 6 shows that at the

end of the traditional unit 47% of students agreed and 28% strongly agreed. By the end of the inquiry unit 55% of students agreed and 32% of students strongly agreed.

The interview results also backed this up. At the conclusion of the traditional unit eight students said that Mr. Heller enjoys teaching science and 1 student said he kind of does.

The reasons they gave included, “He laughs,” “He tries to make it fun,” and “It seems like he enjoys helping kids.” Although these were good reasons, students were much more convincing with their reasons after the inquiry unit. All students said that Mr.

Heller enjoys teaching science and some of their reasons included, “Oh my gosh, he loves teaching science,” “He likes watching us doing the science on our own and making our own improvements,” and “It was like he was watching his kids walk for the first time.”

Inquiry activities provided students with opportunities to experience “ah ha” moments when their research or experiments led to new learning. Some of the new learning was surprising for me and led to several “ah ha” moments for myself.

One theme I found is that I had fewer entries during the inquiry unit than the traditional teaching unit. A possible explanation for this is that the inquiry activities took longer to set up and prepare for than the activities during the traditional unit. This left me less time for completing journal entries. Perhaps once these inquiry activities become routine parts of my classroom they will not require as much prep time, but right now they are still a bit new to me. So I am still really creating the activities.

A second theme I found from my journaling was that during the inquiry unit I more regularly checked in with small groups or individual students. This was evident through journal quotes like, “I really enjoyed traveling between groups today.” By

checking with students more regularly I felt I had a better pulse on my students learning. Because the students were self-directed I checked in with each group approximately three times during a class period.

A third theme I noticed in my journaling was frustration at the inability of the lower ability group to direct their own learning. This can be evidenced by journal quotes such as, "Behavior got in the way a couple times. Groups with students labeled with Emotional Behavioral Disorders (EBD) struggle when there is a disagreement. The group then doesn't function well until Mr. Heller solves the problem." Even with myself and a special education teacher in the classroom, we were not able to keep all groups moving forward with their learning. This leads me to believe that the lower level students may see more benefit from inquiry if they were not all placed in the same class. If these students were paired with stronger ability students, the groups may socially function more efficiently, allowing a higher degree of learning to take place.

Overall, students showed more growth on traditional multiple choice questions during the traditional teaching unit. However, on a performance task assessment students performed higher after the inquiry instruction. Student engagement and motivation increased during inquiry teaching, but confidence stayed relatively the same. The overall impact on the teacher was that my engagement and enthusiasm was increased.

INTERPRETATIONS AND CONCLUSIONS

The overall research question asked how inquiry impacted student's ability to analyze data and draw conclusions. As measured by both the Tables and Graphs Test and the Performance Tasks, inquiry learning improved students' ability to analyze data and

draw conclusions. Inquiry teaching had the largest impact on higher achieving learners' and males' ability to analyze data and draw conclusions. It had a smaller impact on average, lower level and female learners.

Although students showed growth during both the traditional teaching unit and inquiry teaching unit, on the Tables and Graphs Test students improved more during the traditional teaching unit than during the inquiry unit. The Tables and Graphs Test was a very traditional multiple choice assessment. Traditional instruction had a higher impact than inquiry instruction on students' ability to analyze data and draw conclusions on traditional multiple choice test questions.

In contrast, on the performance assessment tasks students showed a greater ability to draw conclusions and analyze data at the end of the inquiry unit than after the traditional unit. The performance assessment tasks required students to use science skills to synthesize prior knowledge and data from the current task. Inquiry instruction had a higher impact than traditional instruction on students' ability to analyze data and draw conclusions on these skills and reasoning based assessments.

Inquiry teaching had a larger impact on boys than girls. While both boys and girls improved as a result of the inquiry unit boy's scores went up significantly more during inquiry. Girls' scores went up significantly more during the traditional teaching unit. These achievement differences can likely be attributed to the fact that boys and girls learn differently. According to Gurian and Stevens (2004) while girls thrive with language tasks, boys prefer mechanical activities. Traditional teaching has a larger focus on reading and writing and inquiry teaching centers around manipulating and doing.

In regard to student ability, inquiry instruction had the largest impact on the high level students. These students performed better on both the Tables and Graphs Test and the performance assessment during the inquiry unit. Middle level learners did better on the performance assessment during the inquiry unit, but showed more growth on the Tables and Graphs Test during the traditional teaching unit. The struggling learners performed almost the same on both assessments during both teaching units. The lower level students had a higher level of off task behavior during the inquiry unit. I feel this may have contributed to the small growth during the inquiry unit. Grouping these students with high and mid-level learners may decrease the off task behavior and allow for more growth to take place.

Student engagement increased during the inquiry unit. When students were given choices about what to study and how to design an experiment that would prove or disprove their questions they showed a high level of commitment to reaching an answer. As engagement increased so did student motivation. When students were working on self-selected topics they were very motivated to work hard to get their questions answered. Student confidence remained about even during both units. I feel this is because while students were posing questions and designing ways to answer these questions it is hard to feel completely confident in yourself. Inquiry naturally lends itself to questioning. Student confidence may increase as they get use to this learning through questioning approach.

Inquiry learning had a greater positive impact on the teacher than traditional teaching. Although traditional teaching allowed for quicker set up of lessons and

materials, the positive impact of inquiry teaching outweighed this savings in time. The students saw the teacher enjoying science more during the inquiry unit. This increased excitement by the teacher can be then passed on to the learners. Another positive that was shown during the inquiry unit was the teacher's ability to check-in and conference with students as an ongoing means of formative assessment. These check-ins allowed me to immediately differentiate for high and low level learners. I could quickly get a struggling group back on track or challenge a high group to investigate further.

VALUE

This action research project has helped me learn many valuable lessons as I continue my teaching. I learned that it will be important to develop my repertoire of inquiry activities and the easiest way to do this will be to modify many of existing activities. I also learned that I will need to plan for my learning space and materials. Additionally, students are eager to share the results of their inquiry projects. Finally, when using inquiry it will be important to consider how students are grouped.

As a result of this action research I have realized that both traditional and inquiry teaching are important to develop well-rounded science students. Inquiry teaching improves students' ability to apply science skills to data and analysis and drawing conclusions tasks. This produces strong science thinkers. Traditional teaching improves students' ability to demonstrate data analysis and drawing conclusions skills on traditional tests. Because students need all of these skills, both teaching methods should continue to be an integral part of my teaching. Students will continue to need solid test taking skills to continue their science education at both the high school and post-

secondary levels. Students also need these skills to perform on the increasing number of standardized tests required in their schooling. The ability to draw valid conclusions will be necessary for many students with a desire to continue into science and many other fields for their career. Drawing conclusions is also a skill that all students will need in order to interpret information from a variety of sources that they may encounter in their daily lives i.e. advertisements, newspapers, internet, books, etc.

My past instruction has focused more on traditional teaching so for me this means I will need to continue to improve my inquiry instruction. My curriculum currently entails a lot of hands on instruction that is teacher directed. I will work to modify these activities to allow students to explore their own questions. As a result of this study I have found that many of the activities I currently do can easily be made into inquiry based activities. I need to modify my planning by spending some time before the activity thinking about what different questions students could ask and what materials they may need to investigate these questions.

It is important to have adequate classroom space available for effective inquiry learning. My classroom is smaller than the other 7th and 8th grade science classrooms in my building. It does not have lab tables or counter space for lab work to take place on. During the inquiry unit students needed space to explore materials and run experiments. This is especially true because students are not all going to explore questions in the same manner or with the same materials. My classroom didn't always have the adequate space to do this. This made it more difficult for students and myself to pursue answers to multiple questions at the same time. In order overcome the lack of space students were

able to configure our tables in any manner to provide the space they required. I also had many students use the hallway as their learning space.

During inquiry it is crucial that as students generate questions for investigation the teacher has sufficient materials for them to use. The last activity of my inquiry unit was very much open inquiry and student directed. In order to do inquiry activities like this I need to be able to utilize my budget effectively so that I have adequate materials available for students to explore for multiple inquiry units. In addition, I needed to be creative in finding places to store the many new materials used in my units. I borrowed space in elementary storage rooms, along with space in our guidance teacher's storage closet and storage in our old home economics room. To help with materials I also encouraged students to bring in their own to enhance their investigations.

Students were eager to communicate their results with others during the various inquiry activities. Since students were not all investigating the same questions, they were more eager to complete a lab write up in order to share results with me and their peers. I could tell they were eager because I had many students ask to use electronic devices to record videos and pictures during the data collection process. They used these pictures and videos in their write up to make their arguments stronger.

My results were shared directly with my sixth grade teacher colleagues and building administrators during our weekly team meeting. This was a great chance for me to discuss with my coworkers how students are grouped. During the inquiry unit the lower level group of students had more off task behaviors than they did during the traditional unit. During the traditional unit students were teacher guided enough that they were able

to stay on task and complete the activities. During the inquiry unit, when they were required to use more high level thinking skills, their off task behaviors increased. They were not self-directed enough to complete the activities without major teacher guidance. This did not allow them to get as much out of the activities as they could have. As a result of our discussions, we are mixing these lower levels students with the higher and middle level students in the next year. If the students who struggle with behavior were in an inquiry group with students of mixed abilities, their behaviors may not surface as frequently because other students would be modeling more focused thinking. Then their behaviors may not be as large of an influence on their achievement. Over time, if only grouped with low level learners or students with behavioral issues these students may lose many opportunities to develop skills that students in mixed groups will more frequently be working on.

Inquiry learning has proven to be a valuable way for students to learn in the science classroom. In my science classroom inquiry improved students' scores, engagement and motivation. Inquiry learning produces students who are able to do more than just take tests. They can authentically use science skills to solve problems. Inquiry learning will increasingly play an important role in my science classroom.

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APPENDICES

APPENDIX A
IMPACT CRATERING



Investigating Impact Cratering



Have you ever wondered why the moon has so many more visible impact craters than the Earth? Do they form differently than craters on Earth? This activity will allow you to investigate many questions you might have about impact craters and how they shape objects in our solar system. It will be your task, as a group, to brainstorm questions for investigation, design an experiment, run your experiment, collect data and communicate your results through a lab report.

Exploration of Materials and Question Brainstorming: Experiment with the materials around the room to help you generate questions about impact cratering. Record them below.

Background Information: As a group decide what parts of the website each member is to read. Record several important pieces of information you learned below. You will share this information with your group. It may be used to help write your background information section of the lab report.

http://www.lpi.usra.edu/education/explore/shaping_the_planets/impact_cratering.shtml

Question for Investigation: As a group decide on a question you wish to test related to impact craters. Record it below.

Data Collection: What type of information are you going to be recording/collecting?

This section may be easier to complete once you have finish the experimental design.

How are you going to record it? How are you going to display it (table, graph, chart, etc..)?

Materials: What materials will you need to run your experiment? List them below.

Experiment Design and Procedure: Explain exactly how you will conduct your experiment. List steps an include drawings.

Experiment Design and Procedure continued...

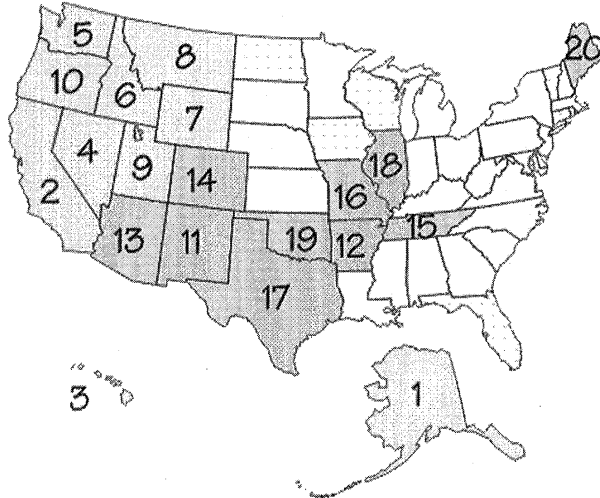
Once you have completed this sheet and had it approved by the teacher then you are able actually run your experiment! Once you have collected all your data, put your materials away and begin the lab.

APPENDIX B
TABLES AND GRAPHS TEST

Tables and Graphs Test

Read each graphic and description carefully to answer each question.

Earthquakes, Magnitude 3.5 and Greater, 1974 – 2003



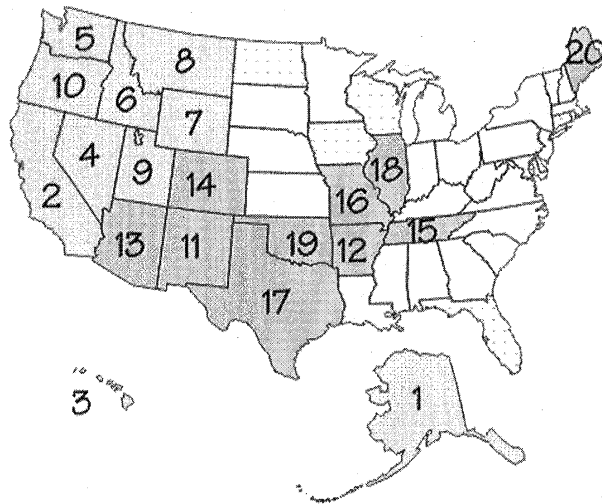
- At least 1 event in 30 years
 0 events in 30 years

Earthquakes, Magnitude 3.5 and Greater, 1974 – 2003

The map above ranks the states based on the number of earthquakes they have experience in a 30 year period. The state with the highest number of earthquakes is given a ranking of 1. The number **does not** indicate the actual amount of earthquakes in the state. (Graphic used from USGS http://earthquake.usgs.gov/earthquakes/states/top_states.php)

- How many Earthquakes did your home state of Wisconsin experienced between 1974- 2003 that were greater than 3.5 magnitude?
 - 0
 - 1
 - 7
 - 18
- What state experienced the second most earthquakes in the 30 year period?
 - Alaska
 - Texas
 - Hawaii
 - California

Earthquakes, Magnitude 3.5 and Greater, 1974 – 2003

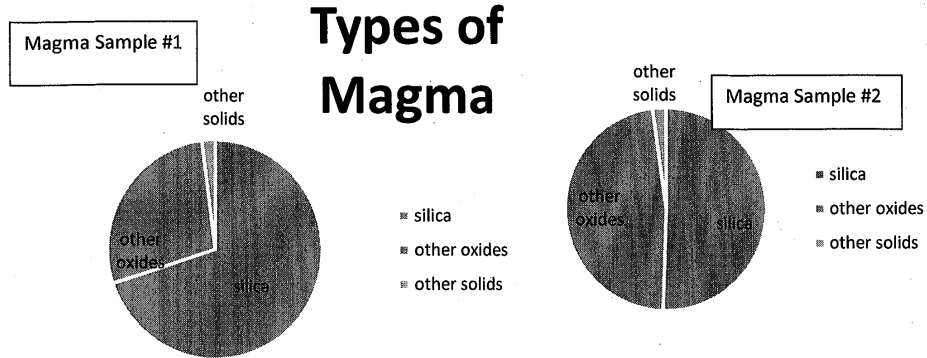


- At least 1 event in 30 years
 0 events in 30 years

Earthquakes, Magnitude 3.5 and Greater, 1974 – 2003

The map above ranks the states based on the number of earthquakes they have experience in a 30 year period. The state with the highest number of earthquakes is given a ranking of 1. The number **does not** indicate the actual amount of earthquakes in the state. (Graphic used from USGS http://earthquake.usgs.gov/earthquakes/states/top_states.php)

3. According to the map, what area of the United States has the most frequent occurrence of earthquakes?
- Great Lakes Region
 - Western United States
 - Eastern United States
 - Southern United States



Magma varies in composition and is classified according to the amount of silica it contains. Magma is a complex mixture, but its major ingredient is silica. Silica is made up of particles of oxygen and silicon. Magma that is high in silica has light-colored lava. The amount of silica in magma helps to determine its viscosity. The more silica magma contains, the higher its viscosity. **Viscosity** is the **resistance** of a liquid to flowing. Therefore, high viscosity liquids do not flow very far. The graphs show the average composition (what they are made of) of two types of magma. Use the graphs to answer the questions.

4. Which magma sample has the most silica?

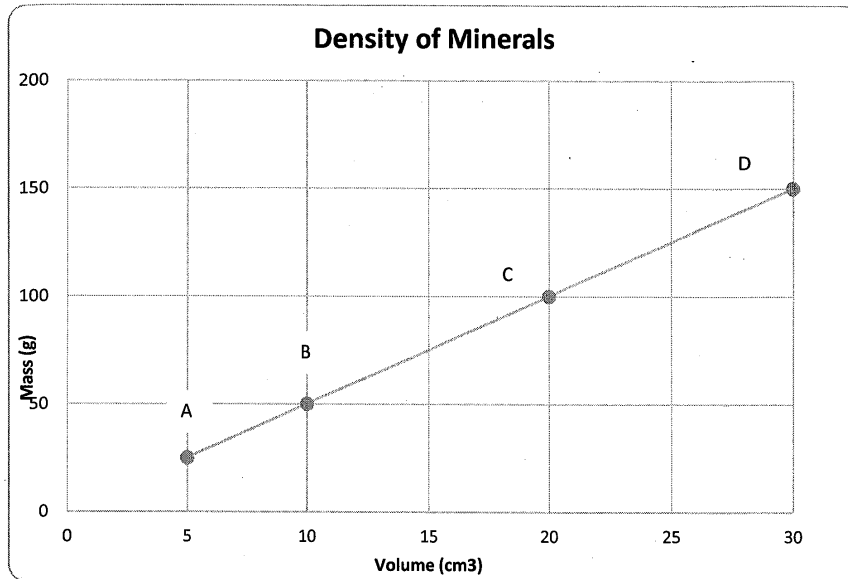
- a. Magma Sample #1
- b. Magma Sample #2

5. About how much silica does Magma Sample #1 contain?

- a. 50%
- b. 70%
- c. 25%
- d. 5%

6. A third magma sample has a silica content that is halfway between the other two types. About how much silica does this magma contain?

- a. 50%
- b. 35%
- c. 60%
- d. 15%



All minerals have a specific density. Density is defined as mass in a given space, or mass per unit volume. Use the line graph of the mass and volume of pyrite (fool's gold) to answer the questions.

The formula to find density is: **Density = (mass) / (volume)**

7. What is the mass of Sample B?

- a. 10g
- b. 25g
- c. 30g
- d. 50g

8. A piece of pyrite has a volume of 40cm³. What is its mass?

- a. 175g
- b. 200g
- c. 225g
- d. 165g

9. Does the density of a mineral sample depend on the size (or volume) of the mineral sample?

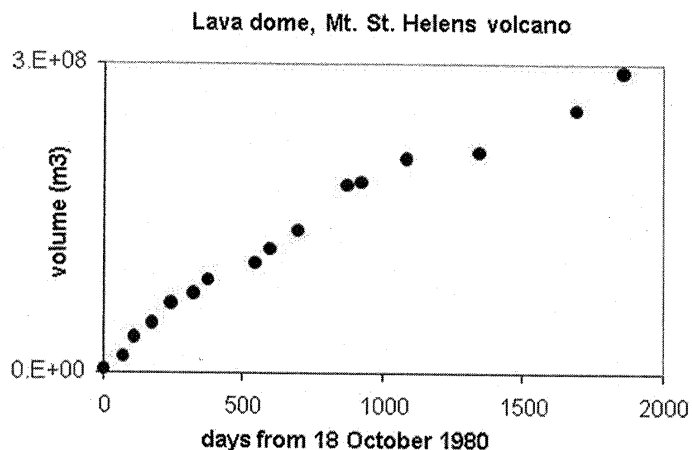
- a. yes, the bigger the sample the bigger the density
- b. yes, the smaller the sample the smaller the density
- c. no, the density is the same for any size of sample
- d. no, density can't be calculated for different sizes

Investigating Urban Heat Islands

Locations in the Schoolyard					
	1	2	3	4	5
Ground cover	Grass and other plants	Asphalt	Gravel	Trees and grass	Asphalt
Sun/shade	Sun	Shade	Sun	Shade	Sun
Average temperature	25.5 C	28.9 C	38.6 C	22.4 C	39.2 C

Students at Parkside School went outside at 2:30 in the afternoon in early June to see if their schoolyard had the same temperature everywhere. They were surprised by what they found. They recorded their results in a data table, which is displayed for you. (Graphic used from UCAR Center for Science Education <http://scied.ucar.edu/>)

10. After viewing the data, what ground cover created the hottest condition on the playground?
- grass and other plants
 - gravel
 - trees and grass
 - asphalt
11. Based on the students' findings, what conclusion could the students make about their data?
- A school in the downtown of a major city would experience warmer temperatures because the concrete and asphalt in the city would cause warmer temperatures all over the city.
 - A school like Parkside which is out in the country would have warmer temperatures because the soccer and football fields near the school would increase air temperatures.
 - On a cloudy day temperatures over grass will not be affected.
 - Schools in big cities will always have cooler temperatures because it will be windy.



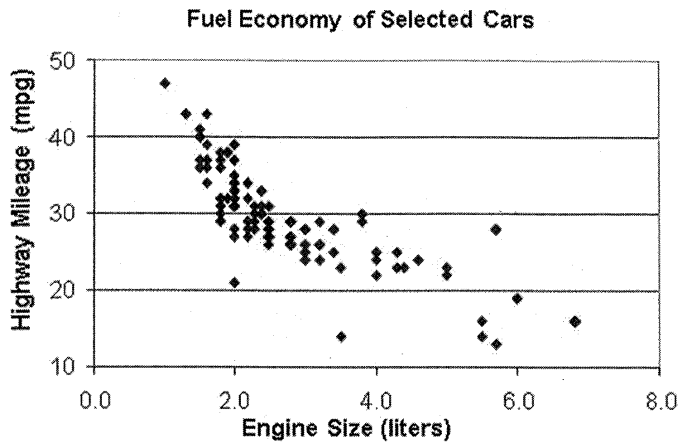
ABOUT LAVA DOME GROWTH AT MT. ST. HELENS VOLCANO

Mt. St. Helens, a stratovolcano in the Cascade Range of Washington State, erupted violently on May 18, 1980. The giant landslides and eruption created a large, horseshoe shaped crater. A dome shape began to form in the crater shortly after the initial eruption. The lava dome grew for the next few years, in short episodes often accompanied by small eruptions. It was expected that the dome would eventually fill the entire crater and start more eruptions of Mt. St. Helens. However, the dome growth stopped in the mid 1980's and the volcano has been very quiet since.

The volume of the dome was measured in cubic meters. A cubic meter is a unit that is one meter wide by one meter in length and one meter tall. Day 0 on the graph refers to the eruption day of May 18, 1980.

(Graphic used from Quantitative Environmental Learning Project <http://www.seattlecentral.edu/qelp/sets/020/020.html>)

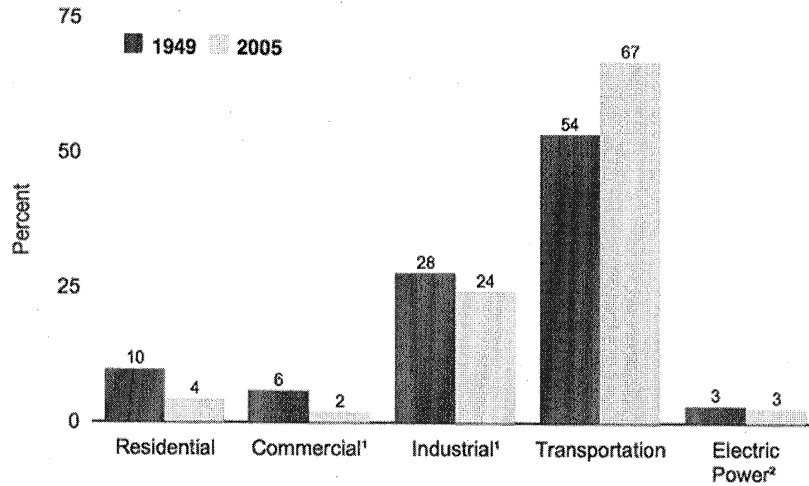
12. During what time period did the lava dome increase at the fastest rate?
- 0-500 days
 - 500-1000 days
 - 1000-1500 days
 - 1500-2000 days
13. During what period of time did the lava dome experience the slowest rate of growth?
- 0-500 days
 - 500-1000 days
 - 1000-1500 days
 - 1500-2000 days



The fuel economy of a vehicle tells a driver how many miles it can travel per gallon of fuel. The US Department of Energy claims that every gallon of gasoline your vehicle burns puts 20 pounds of carbon dioxide into the atmosphere, and that choosing a vehicle that gets 25 rather than 20 miles per gallon will prevent 10 tons of carbon dioxide from being released over the lifetime of your vehicle. Consequently, consumers can greatly influence the amount of CO₂ emissions by making smart choices about the automobiles they drive.

14. According to the scatter plot the majority of cars with a 2.0 liter engine or less will get what type of gas mileage?
- 10-20 mpg
 - 20-30 mpg
 - 30-40 mpg
 - 40-50 mpg
15. According to the scatter plot how do car engines between 2.0 and 4.0 liters compare to cars with engines between 4.0 and 6.0 liters in terms of their gas mileage?
- all 2.0-4.0 liter engines have better mpg than any 4.0-6.0 liter engines
 - all 4.0-6.0 liter engines have gas mileage less than 20 mpg and all 2.0-4.0 engines have gas mileage between 20 and 30 mpg
 - most 2.0-4.0 engines average 25-30 mpg and most 4.0-6.0 engines average 20-25 mpg
 - both engines average the same mpg
16. Based on the scatter plot how does engine size relate to miles per gallon (mpg)?
- as engine size increases mpg increases
 - as engine size increases mpg decreases
 - engine size doesn't have an impact on mpg
 - as engine size increases mpg increases then decreases

**Oil usage by different parts of the United States Economy.
Sectors Shares, 1949 and 2005**

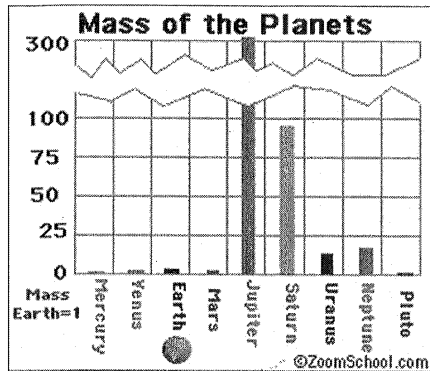


(Graphic used from U.S. Energy Information Administration <http://www.eia.gov/totalenergy/data/annual/index.cfm>)

17. What sector (part) of the United States Economy is using the most oil as of 2005?
 - a. residential
 - b. commercial
 - c. industrial
 - d. transportation

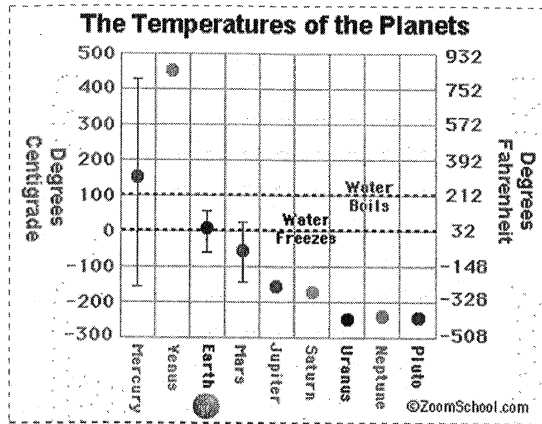
18. What sector (part) of the U.S. economy had the biggest decline in oil usage from 1949 to 2005?
 - a. residential
 - b. commercial
 - c. industrial
 - d. transportation

19. What conclusion can we draw from the graph?
 - a. most sectors of the economy cut their oil usage in half from 1949 to 2005
 - b. most sectors of the economy had small increases in their oil usage from 1949 to 2005
 - c. most sectors of the economy except for transportation and electric power increased their usage of oil from 1949 to 2005
 - d. most sectors of the economy except for transportation and electric power decreased their usage of oil from 1949 to 2005



(Graphic used from Enchanted Learning <http://www.enchantedlearning.com/subjects/astronomy/planets/>)

20. What conclusion can we draw from the *Mass of Planets* graph?
- Saturn has two times the mass of Neptune.
 - The rocky planets have less mass than the gas planets.
 - The mass of the gas planets cause them to orbit faster.
 - The low mass of the rocky planets allow them to have a lot of moons.



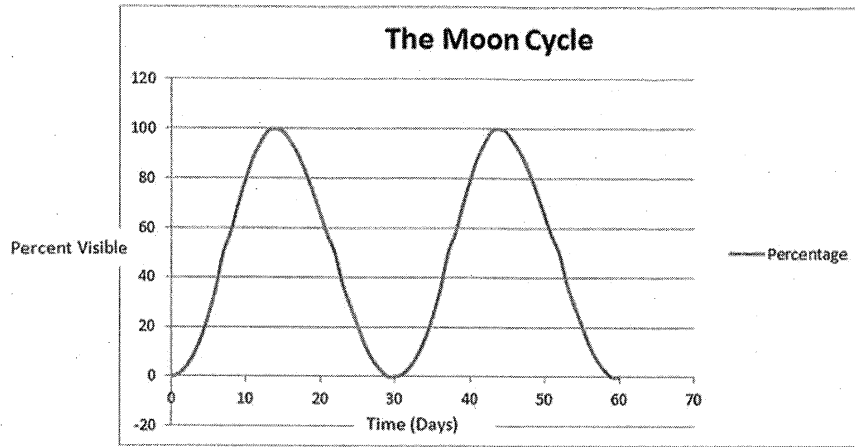
Use the graph called *The Temperatures of the Planets* to answer questions 21 and 22.
 (Graphic used from Enchanted Learning <http://www.enchantedlearning.com/subjects/astronomy/planets/>)

21. What planets have an average temperature greater than 212 degrees Fahrenheit?

- a. pluto and Neptune
- b. Jupiter and venus
- c. mercury and venus
- d. earth and mercury

22. What conclusion can be drawn from the data on the temperature graph?

- a. in general , temperatures go down as you get closer to the sun
- b. in general, temperatures go down as you get further from the sun
- c. in general, temperatures go down, then up, then stay the same as you get further from the sun
- d. there is no conclusion that can be drawn because the data has no general pattern



Use the graph called The Moon Cycle to answer questions

(Graphic used from The Sinusoidal Moon <http://thesinusoidalmoon.wikispaces.com/The+Sinusoidal+Graph>)

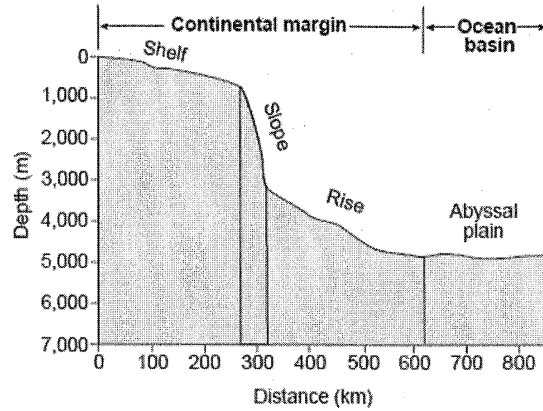
23. When looking at the moon cycle graph what days will the moon be a full moon.

- a. days 10 and 40
- b. days 14 and 44
- c. days 0 and 28
- d. days 20 and 50

24. Predict the next day the moon will be 60% visible.

- a. day 70
- b. day 80
- c. day 90
- d. day 100

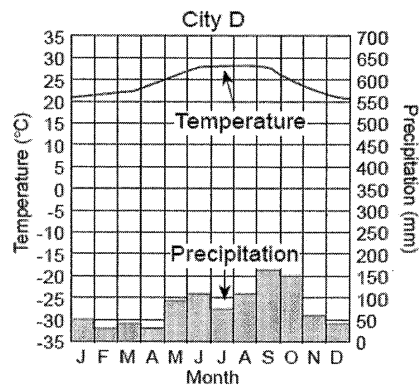
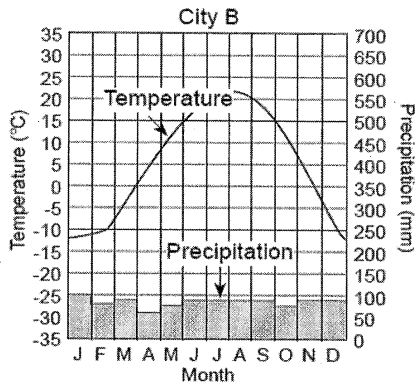
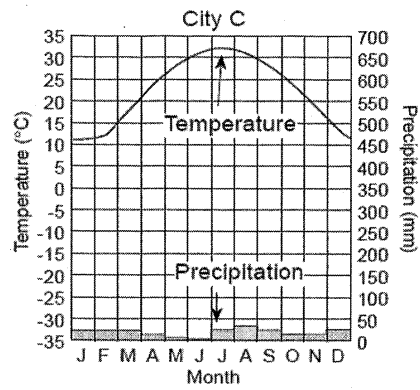
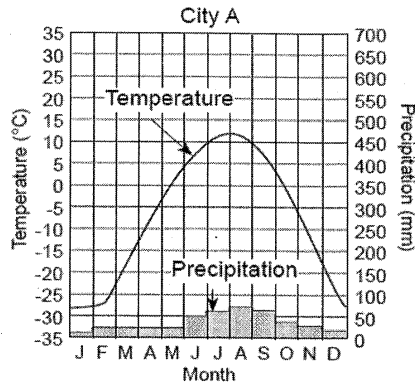
The profile below shows four regions of the ocean bottom.



(Graphic used from New York Regents Exam <http://www.nysedregents.org/earthscience/>)

25. In which list are these regions arranged in order of gradient (slope) from least steep to most steep?

- a. rise -> abyssal plain -> shelf -> slope
- b. slope -> rise -> shelf -> abyssal plain
- c. abyssal plain -> shelf -> rise -> slope
- d. shelf -> abyssal plain -> rise -> slope



(Graphic used from New York Regents Exam <http://www.nysedregents.org/earthscience/>)

26. For which cities is the winter precipitation most likely to be snow? (Hint: 32 degrees Fahrenheit is the same as 0 degrees Celsius)

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

27. In which sequence are the cities listed in order of decreasing AVERAGE YEARLY precipitation?

- a. A, B, C, D
- b. B, D, A, C
- c. C, A, D, B
- d. D, C, B, A

APPENDIX C
PERFORMANCE ASSESSMENT RUBRIC

Performance Assessment Rubric

Tasks				
Data Table				
A. completed data table	0	1		
B. data is recorded in the correct unit	0	1		
C. accurate data	0	1		
Graph				
A. axes labeled	0	1		
B. correct units	0	1		
C. appropriate scale	0	1		
D. data correctly plotted	0	1 75% of points correctly plotted	2 all points correctly plotted	
E. line graph drawn	0	1		
Comments on the above:				
Analysis	0	1 demonstrates an acceptable level of understanding	2 demonstrates a high level of understanding	

Comments on the above:				
Synthesis	0	1	2	
		demonstrates an acceptable level of understanding	demonstrates a high level of understanding	
Comments on the above:				
Evaluation	0	1	2	3
		demonstrates some level of understanding	demonstrates an acceptable level of understanding	demonstrates a high level of understanding
Comments on the above:				

Total Score _____ /16

APPENDIX D
CRUSTAL SINKING PERFORMANCE ASSESSMENT

Crustal Sinking

Task with Student Directions

Grade 5-8 Performance Task

Contributed by: New York State Education Department (NYSED)

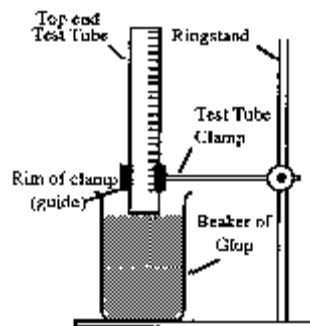
NYS Alternative Assessment in Science Project (1996)

Task:

At this station, you will observe and analyze a model of the interaction between the Earth's crust and upper mantle.

Materials:

- 1 250 ml beaker containing glop
- 1 timer
- 1 ring stand
- 1 test tube clamp
- 1 test tube with scale



Background:

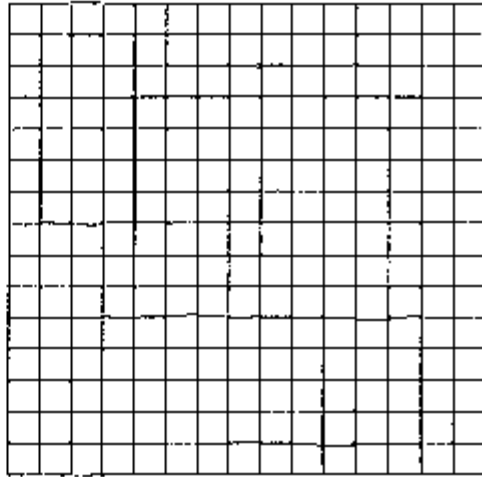
Some geologists believe the theory that there is a semi-fluid layer 100 to 300 kilometers below the Earth's surface. Due to high temperature and pressure, the rock in this region behaves both like a solid and a liquid. Slow movements in this region are thought to be related to changes in the upper crust and to fractures in the Earth's surface. The model in this activity may demonstrate how these changes can occur.

Directions:

1. Set up the equipment exactly as it appears in the diagram above.
2. Before installing the test tube clamp on the ring stand, adjust the opening of the clamp so that the test tube will slide easily through it. ****The clamp will not be used to hold the test tube, but rather to guide its movement.****
3. Place the test tube within the clamp and directly over the glop in the beaker. Hold the test tube above the glop, but do not allow it to rest on the glop yet.
4. Turn the test tube so that the lines and numbers can be read easily.
5. Carefully hold the test tube so that it just touches the surface of the glop. Using the bottom rim of the clamp as your guide, make sure that the scale on the test tube reads zero.
6. Release the test tube and start the timer.
7. Read the level of the test tube to the nearest tenth of a centimeter every half minute. For each reading, record the level using the rim of the clamp as your guide (refer to above diagram). Take readings for a maximum of 5 minutes.

8. Record your observations regarding the level of the graduated test tube in the table below. Make a line graph of your data using time and change in level as your variables. Label both axes. Include proper units.

Time (in minutes)	Change in Level (in centimeters)
0.0	0.0
0.5	
1.0	
1.5	
2.0	
2.5	
3.0	
3.5	
4.0	
4.5	
5.0	



9. Assume that your data is an accurate model for the behavior of a mountain range such as the Himalayas or the Adirondacks. How would the **rate** of sinking of the mountains early in their formation compare with the rate late in their development? Answer in complete sentences.

10. Based on your observations of this model, explain one possibility why the crust is usually pushed deeper into the earth below old mountains than under newly formed mountains. Answer in complete sentences.

11. List at least three factors in the natural world that have not been accounted for in this model.

APPENDIX E

SCALE MODEL OF THE SOLAR SYSTEM PERFORMANCE ASSESSMENT

Solar System Scale Model

Performance Task

The National Aeronautics and Space Administration (NASA) is sponsoring a contest for students. The student who creates the best map of the planets in our solar system will get to go to a NASA Space Camp for a week. As a part of the contest, students are asked to make an accurate representation of the relative distances of the planets from each other. The average distance between the Sun and the planets are shown on the chart below, measured in millions of km.

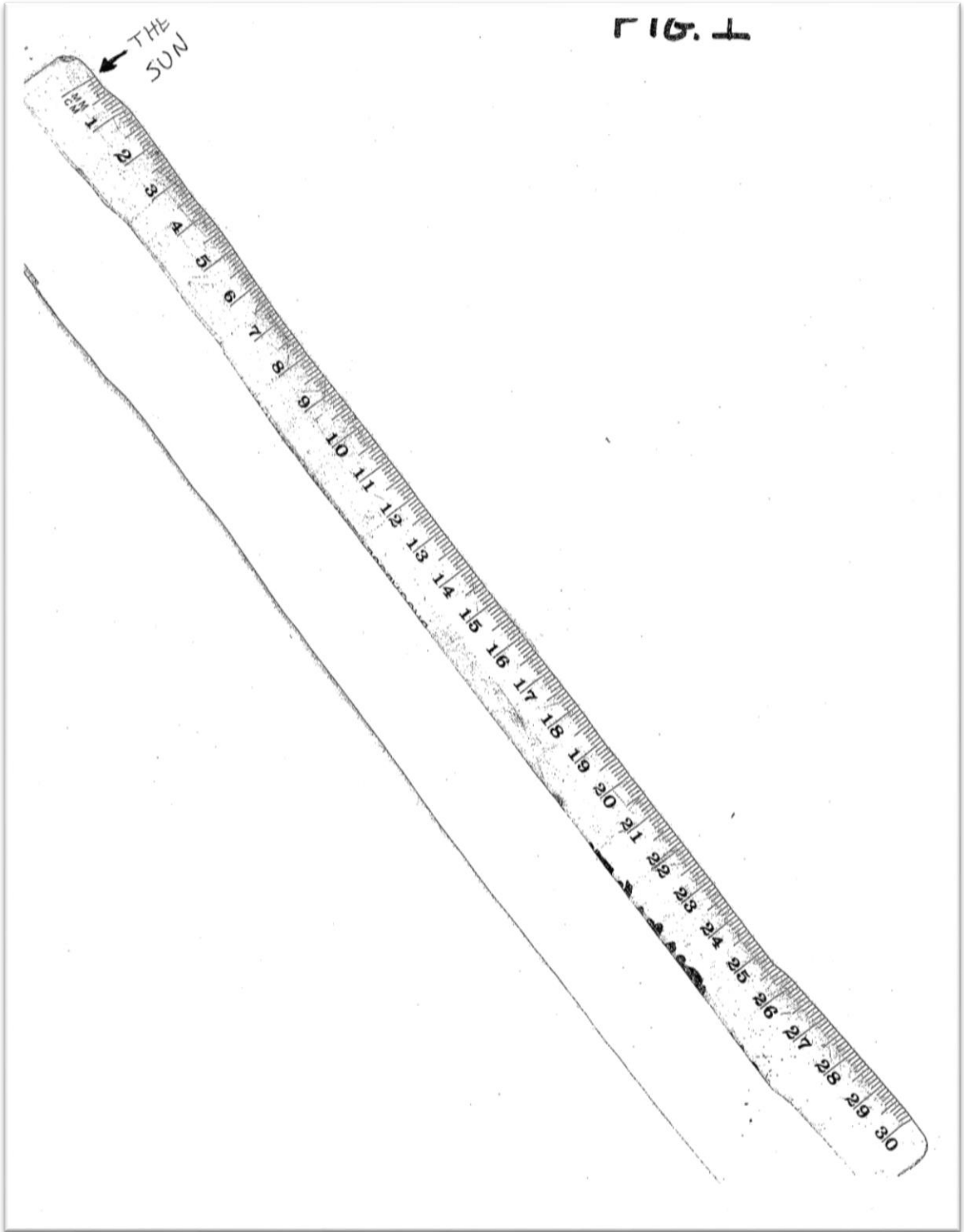
Planet	Distance from the sun in millions of km	Distance from the sun in mm
Comet Heller	75	
Mercury	58	
Venus	108	
Earth	150	
Mars	228	
Jupiter	780	
Saturn	1430	
Uranus	2280	
Neptune	4510	

1. Look at Figure 1 on the next page. You will notice that the sun is placed in the upper left hand corner of the page. It is your job to determine where all the planets should be placed. Use the scale and fill in the chart above to help you place the planets on your map. An example has been done for you.

Scale

1mm = 15 million km

1b. Create a bar graph that displays the planets distance from the sun in **millions of km**.



2. The length of a planet's "year" can be defined as the amount of time, in Earth years it takes a planet to go once around the Sun. If the average speed of a planet around the Sun decreases with distance from the Sun, which planet has the longest year and which planet has the shortest year? (*Note: You do not have to tell the length of the planet's year*) Be sure to explain your answer.

3. Which planet has a year that is closest in length to Earth's year? Explain your answer. (*Your graph, chart and map are good resources to use*)

4. Suppose you were planning a space flight from Earth to Mars. The distance between the planets is 78 million km. A friend of yours proposes traveling along a straight line between the planets. Explain why a straight line of travel between Mars and Earth is not practical (*not a very good idea*). Be sure to explain your answer.

APPENDIX F
TIME ON TASK RECORDING CHART



Classroom Observation Form 4 Time on Task Chart

Teacher Observer	Subject	Number of Students	
		Start/End Time	
Interval	Task, Activity, Event, Question	Off-Task Behaviors (Note # of students)	Teacher Management Strategy
5 min.		Disrupting Others _____ # Visibly Disengaged _____ #	Verbal _____ 0 Nonverbal _____ 0 Positive _____ 0 Negative _____ 0 Comments:
10 min.		Disrupting Others _____ # Visibly Disengaged _____ #	Verbal _____ 0 Nonverbal _____ 0 Positive _____ 0 Negative _____ 0 Comments:
15 min.		Disrupting Others _____ # Visibly Disengaged _____ #	Verbal _____ 0 Nonverbal _____ 0 Positive _____ 0 Negative _____ 0 Comments:
20 min.		Disrupting Others _____ # Visibly Disengaged _____ #	Verbal _____ 0 Nonverbal _____ 0 Positive _____ 0 Negative _____ 0 Comments:
25 min.		Disrupting Others _____ # Visibly Disengaged _____ #	Verbal _____ 0 Nonverbal _____ 0 Positive _____ 0 Negative _____ 0 Comments:
30 min.		Disrupting Others _____ # Visibly Disengaged _____ #	Verbal _____ 0 Nonverbal _____ 0 Positive _____ 0 Negative _____ 0 Comments:

Notes:
 Disrupting Others includes students who are not only off-task, but also are distracting others from the teacher-assigned tasks.
 Visibly Disengaged includes students who are not focusing on the teacher-assigned tasks (e.g. daydreaming), but who are not distracting other students.
 Teacher Management Strategy is any action taken by the teacher in response to (or in anticipation of) a lack of attention by students.

APPENDIX G
ATTITUDES TOWARDS SCIENCE SURVEY

Attitudes towards Science Survey

Participation in this research is voluntary and participation or non-participation will not affect a student's grade or class standing in any way.

Rate the following statements honestly.

Name

Group

1. Science is fun.

Strongly Agree

Agree

Neither agree nor disagree

Disagree

Strongly disagree

2. I do not like science and it bothers me to have to study it.

Strongly agree

Agree

Neither agree nor disagree

Disagree

Strongly disagree

3. During science class, I am usually interested.

Strongly agree

Agree

Neither agree nor disagree

Disagree

Strongly disagree

4. I would like to learn more about science.

Strongly Agree

Agree

Neither agree nor disagree

Disagree

Strongly disagree

5. Science is challenging to me.

Strongly agree

Agree

Neither agree nor disagree

Disagree

Strongly disagree

6. Using math makes science more difficult.

Strongly agree

Agree

Neither agree nor disagree

Disagree

Strongly disagree

7. Graphs are difficult for me to understand.

Strongly agree

Agree

Neither agree nor disagree

Disagree

Strongly disagree

8. Science data is boring.

Strongly Agree

Agree

Neither agree nor disagree

Disagree

Strongly disagree

9. When I see science data, I am eager to understand it.

Strongly agree

Agree

Neither agree nor disagree

Disagree

Strongly disagree

10. When I collect science data, I am confident I will come up with a possible solution.

Strongly agree

Agree

Neither agree nor disagree

Disagree

Strongly disagree

11. Mapping the ocean floor was exciting to me.

Strongly agree

Agree

Neither agree nor disagree

Disagree

Strongly disagree

12. I worked hard while mapping the ocean floor.

Strongly agree

Agree

Neither agree nor disagree

Disagree

Strongly disagree

13. I felt confident that I correctly identified my sea floor structure.

Strongly agree

Agree

Neither agree nor disagree

Disagree

Strongly disagree

14. Mr. Heller enjoys teaching science.

Strongly agree

Agree

Neither agree nor disagree

Disagree

Strongly disagree

APPENDIX H
INTERVIEW QUESTIONS

Interview questions on student motivation, engagement, confidence and effect on the teacher.

To be used at the end of non-treatment and treatment units.

Participation in this research is voluntary and participation or non-participation will not affect a student's grade or class standing in any way.

1. In the past 5 weeks what is the most exciting thing we did in science class?

What did you like about this activity?

2. In the past 5 weeks what is the least exciting thing we did in science class?

What did you dislike about this activity?

3. In the past 5 weeks what is the hardest or most difficult thing we did in science class?

What would have made it easier to do?

4. Do you think you are good at making graphs?

Reading a graph?

Making a conclusion based on a graph?

What do you think I could do to help you get better at these?

5. What activities made you curious or want to know more in the last 5 weeks?

6. What things were boring to you?

7. Do you think Mr. Heller likes teaching science?

How can you tell?

8. In the last 5 weeks what activities did Mr. Heller seem most excited about?

Least excited about?

9. Which activities seemed to make Mr. Heller the most frustrated?

APPENDIX I
DATA COLLECTION TIMELINE

Data Collection Timeline

It is important to note that because of our schools block schedule it takes almost two days to get through one lesson with all five groups of sixth grade students I teach. I see each group for three, seventy-five minute blocks each week.

October 16,17 - collect baseline data using Tables and Graphs Non-Treatment Pretest

October 20 - begin five week non-treatment unit on plate tectonics

October 21,22 - collect time on task engagement data round 1 (10min video observations)

October 28,29 - collect time on task engagement data round 2 (10min video observations)

November 4,5 - collect time on task engagement data round 3 (10min video observations)

November 4, 5 – administer Likert scale surveys

November 17 through 21 - conduct student interviews

December 1, 2 - administer Likert scale surveys and non-treatment performance assessment

December 3, 4 – administer Tables and Graphs Non-Treatment Post Test ***This same test will serve as the Tables and Graphs Treatment Pre Test***

December 5 - begin 5 week treatment unit

December 9,10 - collect time on task engagement data round 1 (10min video observations)

December 16,17 - collect time on task engagement data round 2 (10min video observations)

December 18, 19 - administer Likert surveys

January 6,7 - collect time on task engagement data round 3 (10min video observations)

January 12 through 16 - conduct student interviews

January 22, 23 – administer treatment unit performance task

January 26, 27 – administer Tables and Graphs Treatment Post test

APPENDIX J

IRB FORM



INSTITUTIONAL REVIEW BOARD
For the Protection of Human Subjects
FWA 0000165

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c/o Immunology & Infectious Diseases
Montana State University
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Telephone: 406-994-6783
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Chair: Mark Quinn
406-994-5721
mqquinn@montana.edu
Administrator:
Cheryl Johnson
406-994-4783
cherylj@montana.edu

MEMORANDUM

TO: Andrew Heller and Walt Woolbaugh
FROM: Mark Quinn, Chair *Mark Quinn*
DATE: November 21, 2014
RE: "The Impact of Inquiry Learning on student's Ability to Analyze Data and Draw Conclusions"
[AH112114-EX]

The above research, described in your submission of November 21, 2014, is exempt from the requirement of review by the Institutional Review Board in accordance with the Code of Federal regulations, Part 46, section 101. The specific paragraph which applies to your research is:

- (b) (1) Research conducted in established or commonly accepted educational settings, involving normal educational practices such as (i) research on regular and special education instructional strategies, or (ii) research on the effectiveness of or the comparison among instructional techniques, curricula, or classroom management methods.
- (b) (2) Research involving the use of educational tests (cognitive, diagnostic, aptitude, achievement), survey procedures, interview procedures or observation of public behavior, unless: (i) information obtained is recorded in such a manner that human subjects can be identified, directly or through identifiers linked to the subjects; and (ii) any disclosure of the human subjects' responses outside the research could reasonably place the subjects at risk of criminal or civil liability, or be damaging to the subjects' financial standing, employability, or reputation.
- (b) (3) Research involving the use of educational tests (cognitive, diagnostic, aptitude, achievement), survey procedures, interview procedures, or observation of public behavior that is not exempt under paragraph (b)(2) of this section, if: (i) the human subjects are elected or appointed public officials or candidates for public office; or (ii) federal statute(s) without exception that the confidentiality of the personally identifiable information will be maintained throughout the research and thereafter.
- (b) (4) Research involving the collection or study of existing data, documents, records, pathological specimens, or diagnostic specimens, if these sources are publicly available, or if the information is recorded by the subjects cannot be identified, directly or through identifiers linked to the subjects.

