

MODELING IN THE CLASSROOM: USING INQUIRY TO INCREASE  
UNDERSTANDING AND MOTIVATION

by

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DEDICATION

This capstone project is dedicated to my wife who has been by my side for over 10 years of schooling, to my father who has been the inspiration for my academic career, and to all of my students who have supported my many attempts at teaching. Many thanks to my mentors, Jason George, and John Graves.

TABLE OF CONTENTS

1. INTRODUCTION AND BACKGROUND .....	1
2. CONCEPTUAL FRAMEWORK .....	3
3. METHODOLOGY .....	7
4. DATA AND ANALYSIS .....	15
5. INTERPRETATION AND CONCLUSION .....	21
6. VALUE .....	22
REFERENCES CITED .....	27
APPENDICES .....	29
APPENDIX A: International Review Board .....	30
APPENDIX B: Constructing an Investigation Survey and Questions.....	32
APPENDIX C: Motivation Survey and Questions .....	35
APPENDIX D: Performance Assessment Rubric.....	38

LIST OF TABLES

1. Data Triangulation Matrix.....14

LIST OF FIGURES

1. Bar Graphs Showing Pre and Post Test Results with Difference and p-score.....	16
2. Bar Graphs Showing Pre and Post Test Results with Difference and p-score.....	18
3. Scatterplot Showing Pre and Post Test Results .....	19
4. Pictures of Pre and Post Conceptual Models .....	20
5. Example of a Lab Write-up from Post-treatment .....	24

## ABSTRACT

Students that participated in this capstone research constructed their own questions from an assigned theme and then created a procedure to collect data. They then established a claim and constructed a conceptual model to explain the scientific concepts in their science inquiry project. The goal of this project was to create an academic atmosphere that promoted creativity and critical thinking and enabled the students to solve real-world problems.

This capstone measured student motivation to complete inquiry projects in the classroom. I wanted to find out if students were motivated to complete class work to please adults or for their own intrinsic reasons. I hoped students wanted to complete work for their own intrinsic reasons. By the use of their own creativity and imagination would solve problems and tasks at hand, they would internalize concepts and gain a deeper understanding of the material. If students completed because they wanted to solve their own questions and not because an adult instructed them to do so, they retain information instead of going through the motions of filling out a worksheet and turning it in for a grade.

The use of formative and performance assessment measured their academic growth and Likert surveys explored their comfort level with the use of inquiry in the classroom as they constructed questions, gathered data, and made claims. Three key factors helped me transition the class from worksheet and lecture driven instruction to the use of inquiry. This was the use of formative assessment, classroom structure, and the implementation of peer-review.

## INTRODUCTION AND BACKGROUND

A successful science classroom is one where students are actively engaged. Heads are bent in inquiry, students strain over their notes, and conversations dart quickly about the problem given by the teacher. It is this type of classroom where scientific principles are eagerly absorbed when the correct conditions are utilized with the use of an inquiry based learning model. The use of inquiry is necessary in an active classroom to challenge students. When instructors use this methodology, students investigate, model, and make a claim to answer the problem presented in the activity. Use of this process will empower student because they use their own imagination and ideas on how best to solve problems posed by the teacher.

Caldwell, Idaho is part of Canyon County that is located in the southwestern portion of the state. The economy is based in agriculture, manufacturing, and construction. Caldwell's most common occupations include factory production workers, drivers, and laborers. Canyon County has a high percentage of the conservative party affiliation, with approximately 65% of the population voting republican and 30% democrat (City-data.com). Vision Charter School (VCS) is a K-12 school that serves a large percentage of underemployed families. Typically, over 43% of the student population at VCS is part of a free and reduced lunch program (Greatschools.org).

In order to serve this population, VCS has partnered with the local state college to offer a dual-credit program. If students follow this path, they can graduate with an Associate's degree along with the traditional high school degree. This is necessary because Idaho high school graduates are not statistically successful in college. Currently,

90% of students' graduate high school, but only 20% have one or two years of college credits (Everitt, 2015).

This capstone project met a critical need for the school and student population. While VCS is academically rigorous and offers dual-credit classes, the majority of students lacked motivation to perform at a higher level of critical thinking. Students in my science classes did not understand concepts in the curriculum even though they used textbooks and in-depth worksheets. They were not excited to learn and sighed with disgust when a new assignment was introduced.

After a graduate class in science inquiry, I knew that it was a process that should be introduced in my classroom. Inquiry enables students to become excited about the learning process. This is because they choose how to complete projects assigned by the instructor. Students complete projects with the use of background knowledge, data gathered from investigations, and their own creativity to construct explanations of scientific phenomenon. Students are more likely to be engaged in lessons and participate in complex and higher order thinking skills. They would also be motivated to deepen and broaden their understanding of material with implementation of scientific inquiry.

I ensured that projects used followed a theme. This allowed the students to complete projects that built on each other in a series of logical concepts versus disconnected labs. The concepts used were scaffolded nine weeks' prior with a climatology module. Students studied physical phenomenon of particles in the ecosystem with weather with this learning activity. This study led to the interaction of particles with the water and soil ecological system with water quality testing, conceptual modeling, and

case study of Selenium released from mining activity.

The focus question for this project was, “*If students construct their own investigation will it help them understand scientific methodology and increase their motivation to complete work in the classroom.*” This project gathered data to determine what, if any, effect integration of inquiry in the classroom had on student motivation. My theory was students would form a deeper understanding of scientific principles when they directed their own learning. The study explored effects of model-eliciting activities on students to deepen their comprehension of scientific methodology. In an effort to enhance understanding of presented material, students created their own essential question, constructed a model, and gathered data to support or reject their claim.

#### CONCEPTUAL FRAMEWORK

Inquiry-based science is a powerful tool in the classroom. Science inquiry is a more open-ended approach that uses the educational background and the creativity of students to form and solve a problem. Use of inquiry should motivate students and increase their self-esteem because they solve problems with a scientific investigation formulated by their imagination. This type of science methodology will empower students when they are allowed to generate their own questions from the scientific theme presented by the instructor (Rothstein & Santana, 2011).

Use of inquiry in the classroom helps the student develop conceptual understanding of scientific phenomenon. This process enables the student by empowering them to decide the best methodology for answering a question. This is different than the typical science investigation that follows a step-by-step procedure with

a defined answer. Students should realize that science is not defined by the phenomenon that is being studied but rather in the construct of the concept that is presented (Konicek-Moran, 2015).

Inquiry in the science classroom is a cycle that engages the student in answering an essential question with an investigation into scientific principles. The first step in this cycle is for the student to design a question that can be investigated. Students need to develop the question from their own backgrounds and imagination (Konicek-Moran, 2015). The students use the question to design an investigation in which they can collect data which leads to the construction of a physical or conceptual model. Data is collected in the next step that the student will use in order to state a claim about the investigation. The final step of the inquiry cycle includes the conclusion leading either back to the claim or to the student posing a new claim (Llewellyn, 2014).

It is important that the students form questions that will lead to the successful completion of the inquiry cycle. *Asking Questions and Defining Problems*, is one of the Next Generation Science Standards (NGSS), (NGSS Lead States, 2013). There is a method that helps the students create a question in a process called the, Question First Technique. This technique begins with the teachers designing an educational focus or theme for the students to construct their investigations. This focus could be presented as a journal prompt, a visual model, or scientific data (Rothstein & Santana, 2011).

The instructor should discuss with the students the qualities that make a good question. These questions need to be open-ended to elicit a testable or debatable response. The students write down as many questions as possible within a given time

frame. This process ensures that there is enough material for the students to peer-edit the questions. As the students edit their questions, it is important for the group to focus their discussion on the type of question that will fulfill the requirements of the instructor (Rothstein & Santana, 2011).

After the questions are chosen, the students need time to reflect on the process. This reflection can be a few sentences written silently in a journal, or a group discussion. The important factor is that the students are given time to think about the reasons for choosing the final questions from the initial set. In order to help the reflection, the instructor should make certain the classroom structure remains intact with time deadlines or rubrics used as a foundation of expectation (Rothstein & Santana, 2011).

Once the testable question has been finalized it can be integrated into the process of constructing a model. The model is used to depict a scientific phenomenon and is a necessary component of science inquiry and investigation. Students will use this model to engage their critical thinking process that will fully incorporate scientific principles learned through lecture and notes in the classroom. The model helps the students understand the concepts of scientific principles presented in class, and students use it to gather data during an investigation. Students need to create a model as specified in the NGSS standards. These models can be physical, mathematic, or conceptual in nature (NGSS Lead States, 2013).

NGSS considers creating a model vital to the ability of students to understand science principles. The standards incorporated the use of models in a science classroom so students will analyze a system and test any flaws or discrepancies that may exist in an

investigation. Students use models to represent scientific systems, numerical values, or analogies. They use a model to gather data and communicate results of the experimentation process. They are used to generate argumentation and investigation. The use of models also allows the students to use their creativity to show the summary or critical parts of the of the science investigation (NGSS Lead States, 2013).

There are several design requirements to meet when students construct a model. The first requirement is to make certain that the students recognize the need to successfully complete a model to complete the investigation. The student-constructed model is built with tools that are conceptual or physical. These tools need to be manipulated to prove their usefulness in solving the initial problem. The instructor's role is to support the students in construction of a model from their own life experiences and background information. When the above requirements are met, it has been shown that the student created model increases in complexity. With this increase, the students' depth of understanding about the scientific principle will increase (Lesh & Lehrer, 2003).

The integration of student-generated questions and modeling in the classroom can be new and challenging for the instructor to implement. The process can include limited time available during class for large inquiry projects. There can also be a concern about finishing curriculum while teaching students how to incorporate this methodology. Implementing conceptual understanding with modeling in a classroom could include instances where students might get stuck in the cycles of inquiry and modeling. The instructor must reflect on the process and outline expectations with the students to alleviate some of these concerns. This will ensure that the transition into the use of

inquiry in the scientific classroom is smooth and that frustration does not hinder the modeling process (Parks, 2014).

## METHODOLOGY

The purpose of this study was to use inquiry in the science classroom in an attempt to engage students and raise their understanding of scientific methodology. The data was collected from two eighth grade physical science classes. The students ranged in abilities from those with learning difficulty to members of the talented and gifted program ( $N=64$ ). They were seated at tables with peers of similar cognitive levels. The seating arrangement helped them design an investigation that was within their learning abilities. This kept the students comfortable in a peer-to-peer environment and enabled them to feel challenged regardless of their cognitive ability. This project received exception from the Montana State's Institutional Review Board and compliance for working with human subjects was maintained (Appendix A).

The changes in classroom procedure from using worksheets and videos to having the students design their own inquiry-based labs started last school year while the students were in seventh grade. During this project I found that the students needed to be trained in each step separately before they used the entire inquiry process to complete a project. I started to build the information until they were comfortable with the initial steps of inquiry last year in science class. Since the students were experienced with the use of inquiry, I was able to start the year with a basic inquiry project that centered on the theme of aeronautics. In September, students completed a pre-assessment unit on aeronautics. This was a non-graded formative assessment meant to gauge students on

their comfort with science inquiry and its methodology. The aeronautic project was completed without any guidance from me and only used as a formative pre-test to judge their comfort level with inquiry.

Instruction of science inquiry was then scaffolded over the treatment period between September to April. Students were then taught how to properly construct a question using the, *Question First Technique*. Once they had practice and could properly design the question, instruction moved to the use of a model to describe scientific concepts. The students were given examples of both physical and conceptual models before they constructed the models.

Three key practices enabled the successful implementation of inquiry-based projects in my classroom; formative assessment, classroom structure, and of peer-review. With formative of assessment, I checked student progress as they constructed their inquiry projects. With every step of the inquiry process, I coached, managed, and tested their abilities as they designed their projects. I talked to each group member as they progressed through the process so I had a full understanding of the comprehension of student comprehension of the material.

The formative assessment began with the addition of strict time requirements as students constructed their projects. This was a necessary step to help the structure classroom management while students completed their tasks. I set a timer in the front of the room and at the end of each timed section had students stand and present their work. This taught them to finish their work because they did not want to be different than their peers who had completed the assignment. When the students presented their work as a

group it acted as a peer-review session and enabled their classmates to change their own questions before they presented. The use of time limits gave needed structure to the students and helped them become more focused in their work efforts.

Classroom management was improved by the use of strict classroom structure. First, I had the students gather background information. This was accomplished by doing research on a subject, defining vocabulary, or writing a summary about reading material. Then I presented a theme from the background information around which they would construct the inquiry investigation. After the theme was written on the board I typically put 5-7 minutes on the timer for them to construct the question. This was followed by the class presentation in which their question was either acceptable or not. If their question lacked or was not in-depth the group continued to work while the rest of the groups presented. After everyone was done, I came back and asked them to re-present their question. Students realized that they needed to complete their work because I would not accept anything less than their best effort. The group presentations acted as a formative assessment for me as I could keep track of how each student progressed with their project. If a student or group struggled with their idea, I could go to their table and help them while the others worked on the next section.

After the question was completed students were required to write a procedure and gather data. I typically gave the class 25-30 minutes to complete this section but that time varied according to the complexity of their project. After the time was reached, groups presented their procedure and the rest of the class and I provided feedback in a peer-review session. If the procedure needed refined, I gave them a few minutes to fix

the problem. Once their procedures were completed they began the data collection.

The use of peer-review helped the students understand how to complete each step. When the students were uncomfortable with a process they could listen to how other groups handled it, which would help them with inspiration to construct their project. The students used peer-review with almost every assignment that was completed from a five-page technical research papers to lab write-ups, everything was peer-reviewed.

The first model they designed gathered data for acceleration and force, this project was titled, "Man vs Machine." The class was asked to construct an experiment where they could calculate acceleration and force. The materials they could use were a truck, a teacher on a longboard, and a student that would run da specified length. They could also use a set of 30 stopwatches and any mathematic formulas they could find to help them calculate acceleration and force.

With the information and materials, the students created a testable question. Their ideas were peer-edited by the entire class as each table stood and presented their questions. The groups sat down and refined their questions and we decided on, "Which accelerated faster, a man or machine over a given distance." After the question was approved, the students started to constructed the procedure to gather the data. During this process I talked to each group and asked how they were going to complete this challenge. This conversation was a formative assessment as I checked to make certain they were collecting the right types of data and their process was feasible.

Before the groups finished, I called the class back together and had each group present their ideas in front of the class. As each group presented, the other students were

able to state any shortcomings with their process. The students knew they had to collect time and distance for each of the three variables but wanted to time only the beginning and end times. We then had a discussion as a class about the need to collect times across the entire length and have a distance that could be split into even intervals. The students went back to their groups and decided on 100 meters with 30 timers set at even intervals. Each student wrote their question and procedure in their lab write-ups they created.

We went outside and set up the course with marked distances and set up the timers. Three students volunteered to run while we timed them, as they ran each student recorded the data. This process was repeated when I ran my longboard and truck down the course. The class went back inside and made tables to share all the data. They then took the raw data and used their formulas to calculate force and acceleration. As part of the process of a completed lab write-up, they drew their own data tables, graphs, and formula calculations. When completed, they made a claim according to the data and wrote a conclusion from their data that supported the claim. To complete this process, they presented their findings as a group in front of the class while the rest of the students cross-examined them to find any fault in their work.

The last investigation of the year focused on having students learn how to test water quality. This unit was chosen because the theme of water quality covered elements, particles, and molecular bonds. I have taught atomic bonding to physical science students for several years. Every time students struggled to understand the concepts of molecules and chemical bonds. My hope was through this capstone project my students would develop a deeper understanding of scientific principles when they used real world

examples and constructed their own investigations.

The water quality study used an ecological model to help students gather data during their inquiry project. An aquaponics unit was built above a 200-gallon classroom aquarium and fitted with pipes and a pump. Chia seeds held in small containers to provide crops were used to represent farm areas. The seeds were placed in enough trays for each table of four students with a total of 16 trays. This was used to create a model of an agricultural environment in which the students were tasked with raising sprouted crops.

The students were given a farm plot in the unit and raised sprouts for a three day growing season. After students left for the day, I added different factors that simulated poor water quality conditions to the irrigation system. The pH levels, nitrates, and phosphorous were all increased in the water with added chemicals. This killed some of the crops and students had to develop an inquiry investigation to determine the cause of plant death. Students used water quality monitoring instruments to determine the source of the pollution, construct a plan for abatement, and regrow their crops.

This capstone study used non-parametric statistical analysis for interval data, this measured equidistant interval matched or paired data. The null hypothesis is the treatment did not enhance the understanding of the inquiry method and the students were not motivated to complete their classwork. If the hypothesis was supported, then the students did feel engaged and empowered to solve real-world problems. They would be motivated to complete their classwork because they had the tools through the scientific methodology to find solutions to their own questions.

Quantitative and qualitative data was analyzed for themes and trends that indicated effects on students when science inquiry and modeling were incorporated into the classroom. A paired sample t-test was used to analyze the Likert-type surveys ( $N=64$ ). The t-test calculations were used to establish a p value. This score was used see if there is a statically significant increase in understanding of scientific methodology between the pre and post survey results. If the p value is less than alpha (which is typically set for 0.05 or 5%) then you fail to accept the null hypothesis, or if the p value is greater than 5% then you fail to reject the null hypothesis.

The students were asked to rate their comfort with the use of scientific methodology introduced in class with the, “Understanding of Scientific Methodology Survey” (Appendix B). This Likert-type instrument that contained ranked statements, from *strongly disagree* to *strongly agree* (quantitative data), and open-ended questions (qualitative data) and administered to students before and after treatment. A paired sample t-test test was used to compare quantitative data from pre and post-test survey responses. A mean p value was calculated to gain quantitative data about the usefulness of the treatment between the pre and post-tests. The survey concluded with open-ended questions that yielded qualitative data about students understanding of the scientific process.

The Motivation for Completing Classwork Survey asked students about their motivation to complete work assigned in class (Appendix C). This survey was used to see if students’ completed classwork for intrinsic or extrinsic reasons. An intrinsic student completes classwork because they want to explore and learn something new and

interesting for themselves. An extrinsically motivated student finishes classwork for a better grade or to please a social agent, such as a parent or classroom teacher. The survey was given post treatment and was designed to provide insight into how inquiry projects affected students and if inquiry is more suited to one motivational type or the other. Pre- and post-survey data was statistically analyzed with a two-tail t-test.

The above sound waves and water quality inquiry activities were graded with performance assessments to measure the successful project completion. Assessments were graded according to the Construct a Science Investigation Rubric, which provided quantitative student data (Appendix D). Students were assessed before they constructed their inquiry project based on a theme presented by the instructor and after project completion. Grades were normalized for gains by subtracting the pre-treatment score from the post treatment score then dividing by the maximum score minus the pre-treatment score. Normalized scores can be compared to determine the significance of student improvement and statistically analyzed (Hake, 1998).

The triangulation matrix below describes the data collection sources used to measure student motivation as they completed their projects (Table 1). Surveys and performance assessments in the table list pre and posts tests given to measure attitudes and performance before and after the treatment.

Table 1  
*Data Triangulation Matrix*

Research question	Data source 1	Data source 2	Data source 3
<i>Research Question</i> If the students construct their own investigation will it help them understand scientific	Pre and Post, Understanding Modeling and the Scientific Methodology Survey with Open-	Pre and Post, Motivation for Completing Work in the Science Classroom Survey with Open-	Pre and Post, Construct a Science Investigation Performance Assessment Rubric.

methodology and increase their motivation to complete work in the classroom.	Ended Questions	Ended Questions	
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## DATA AND ANALYSIS

Figure 1 presents results for the first survey, Understanding Modeling and the Scientific Methodology. A calculated mean p value of 0.174 indicates a failure to reject the null hypothesis. Even though there was little statistical evidence for the treatment success, qualitative data gained from the open-ended questions indicated students felt the treatment was successful. One student stated that she thought the labs were, “hard at first but they got easier.” The student said she enjoyed the labs after some practice with the process, “once you got the hang of doing them, they became more fun to do.” The result of this calculation shows that the treatment did not change the comfort level of the students. The calculated mean score showed that *I agree* was the most picked answer as the students answered the survey. The next calculation showed the differences between the pre and post treatments. The values were similar and showed little increase or decrease during the two testing cycles. Eight of the 12 questions had negative values between the initial and final surveys.

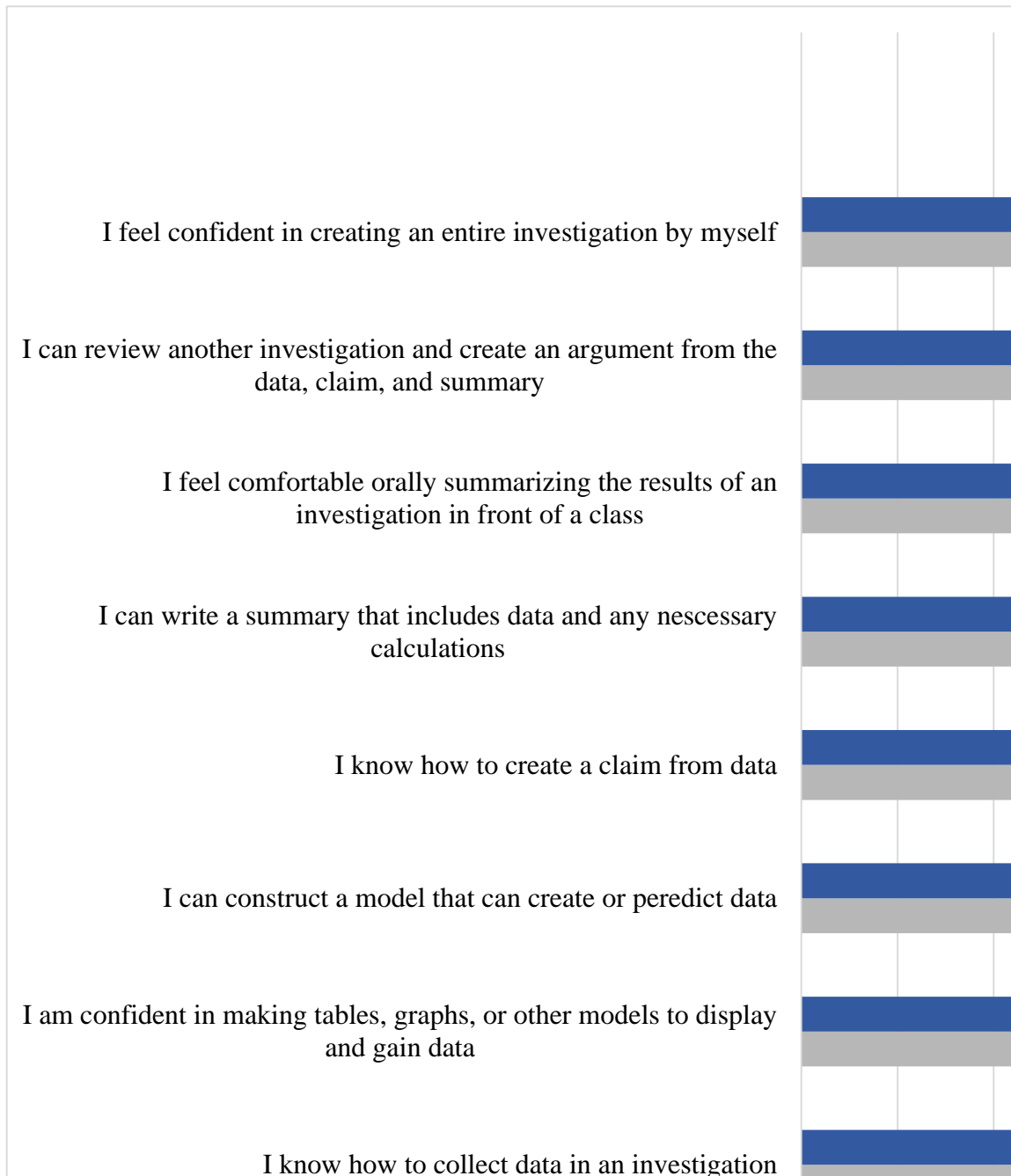


Figure 1. Understanding Modeling and the Scientific Methodology pre and post survey results (N=64). Note. Value of 0 is *strongly disagree* to value of 4 being *strongly agree*.

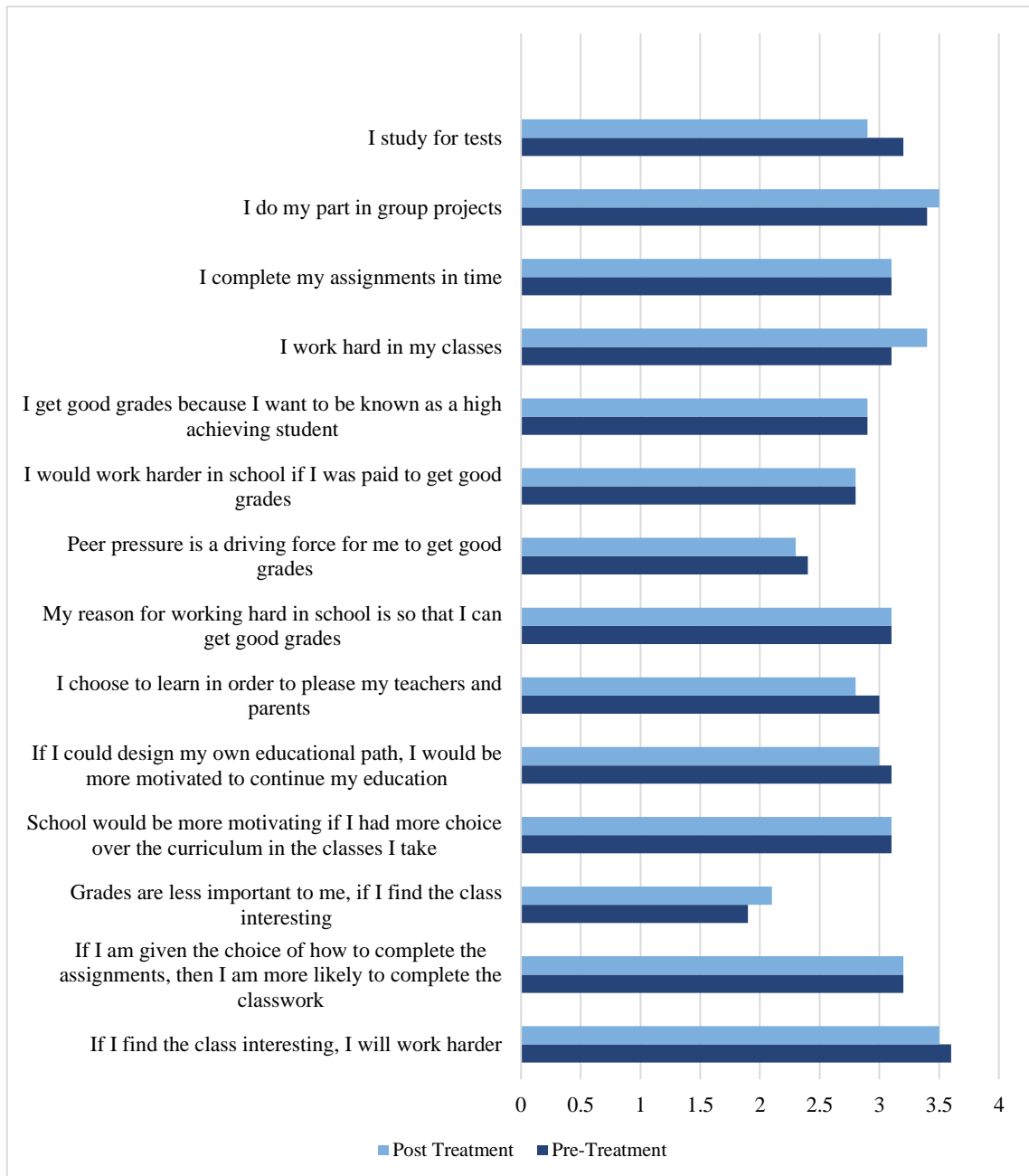
The second Likert-type survey, Motivation for Completing Work in the Science Classroom Survey, had a calculated p value of 0.21 (Figure 2). This value is also higher than the prescribed alpha ( $0.21 > 0.05$ ), which indicates a failure to the null hypothesis

that there is no significant difference in student motivation levels. The open-ended questions provided qualitative insight that the students work harder in class for both intrinsic and extrinsic reasons.

One of the students demonstrated her intrinsic motivation by stating, “I work hard because I want a good grade... I work hard for myself.” Another student commented, “I don’t care if I please my teachers or parents...I have the grades I want.” One student also said, “If I were the student, I would choose to finish the assignments my way,” to answer the open-ended question on student designed curriculum.

When asked to explain the reason why they work hard in the classroom, a student replied, “I like to work hard because the material is interesting and engaging.” A student stated their intrinsic motivation with, “I like it when I can think on my own and no one tells me how it is.” One student answered the question with, “No, I choose my own path, even if it is a terrible teacher I would still work hard.”

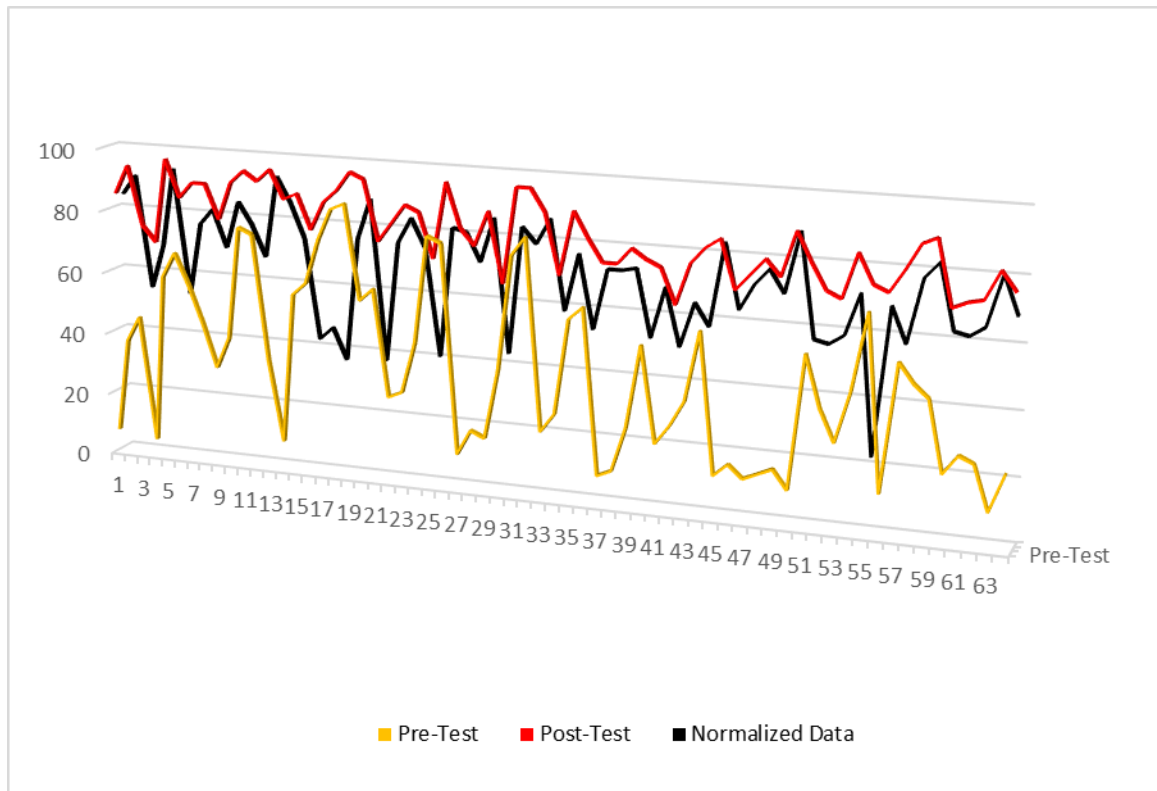
This survey asked the students if they worked hard because the class material was exciting and engaging. The replies were intrinsic in nature and shared the students’ enthusiasm for completing project-based inquiry. A student observed, “If you look around, the people working the hardest are the one’s usually having the most fun.” Another student confirmed this with, “Yes! I love it when we do group projects where we are engaged in the assignment. It makes me want to do well on the work.”



*Figure 2.* Motivation for Completing Work in the Science Classroom Survey pre and post survey results, ( $N=64$ ). Value of 0 is *strongly disagree* to value of 4 being *strongly agree*.

The performance assessment, Construct a Science Investigation Performance Assessment Rubric, showed a substantial increase from pre to post treatment administration (Figure 3). The scores from the pretest showed a median result of 40%,

while the posttest resulted in scores with a median of 82%. The median differences between the pre and post-test displayed an increase of 41 points. The median post-test scores of 82% were 41 percent higher than the median pre-test score of 41%.



*Figure 3.* Construct a Science Investigation Performance Assessment Rubric pre and post test results, ( $N=64$ ). *Note.* The X values indicate individual students.

Figure 4 is a pre and post conceptual model that students used to explained the phenomenon of weather. The first picture is a pre-model that illustrated what the student understood about weather. The second picture is the post-conceptual model drawn after the treatment. The information in the post picture is more elaborate and filled with specific detail and explanation. The post conceptual model shows the improvement in qualitative detail of this student's understanding of scientific phenomenon.

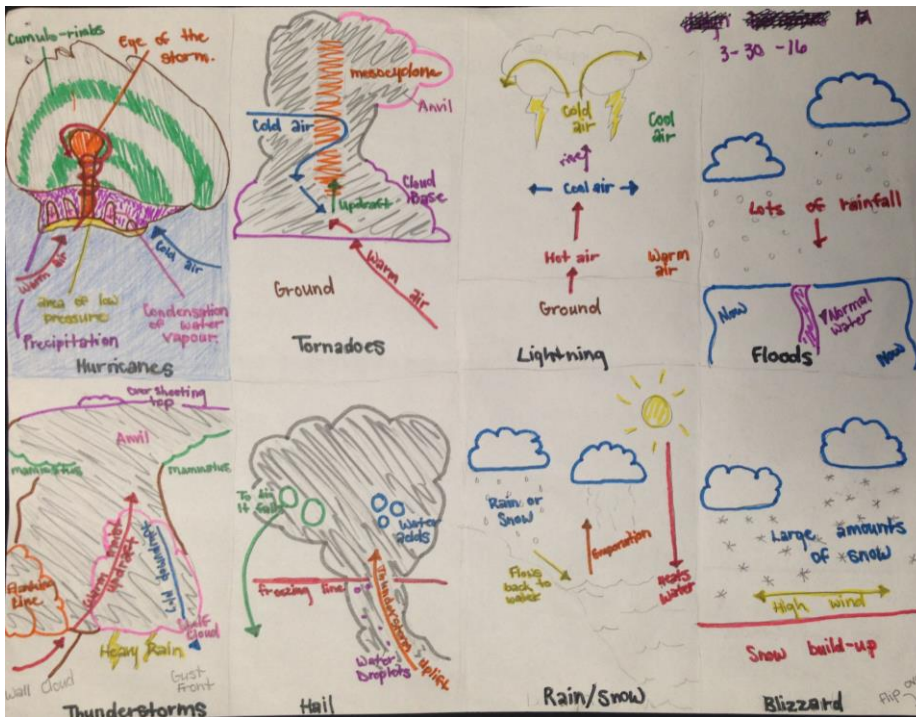
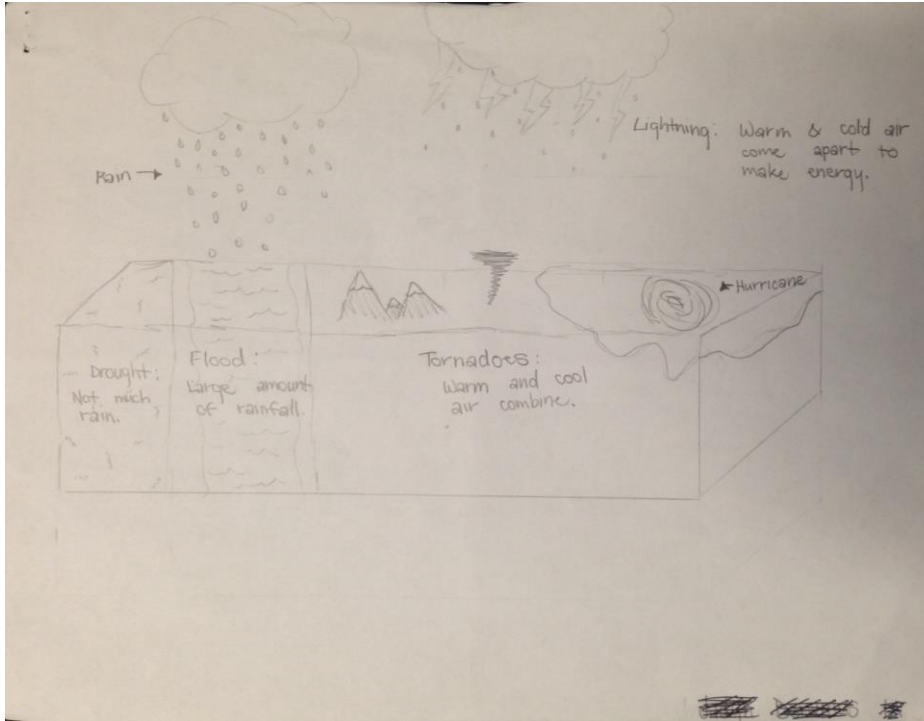


Figure 4. Pre- (top) and posttreatment (bottom) weather conceptual model.

## INTERPRETATION AND CONCLUSION

Results from the data analysis were mixed as far as growth or increase in motivation about completing class work. I had hoped that after the treatment period my students would be very comfortable in the inquiry process. However, after seeing the results from the inquiry survey, I feared that the students did not feel more confident as they constructed a question, collected data, and established a claim. Their lab assessment scores improved dramatically, so the increased performance assessment scores coupled with the declining survey scores did not make sense. Then I realized that pre-treatment survey results indicated students only thought they felt comfortable with the inquiry process. However, as they incorporated the steps of inquiry into an investigation, they realized there was more to the process than they initially thought. This would explain how performance assessment scores rose while survey values declined.

When I first started the implementation of inquiry, many students found they were challenged and frustrated while they learned the new methodology. One student stated, "I've enjoyed this year but I've learned I hate not having instructions on what to do," then contrasted with, "Yet, I like it at the same time, it's honestly way more fun than a worksheet." Most of the students felt this way during the treatment. They were bitter when the methodology was introduced. At the end of the year they said they really enjoyed being pushed and made to use their creativity and imagination. I thought I had pushed them too far, but the same student from above reassured the process with, "I learn more when I'm stressed... but I hate being stressed. I wish every science class was like this."

There were many instances in class where I had to act as a motivator so students would not just give up and submit work that did not meet my requirements. When we first started to use the open-ended approach of inquiry, some students wanted to be told what they needed to do to complete the process because they were used to lab write-ups with detailed step-by-step instructions. One frustrated student stated she, “hated these labs!” By the end of the same student stated that she a struggled with the inquiry process because she really loved being told what to do to get the perfect grade and, “it has been hard for me to trust my own ideas.”

After they had used the inquiry process to complete labs in the first of the school year, some other students really enjoyed the being able to solve problems on their own. Another student said she really struggled to understand the information at the beginning of the year. She could not keep up with the pace of learning the labs because it was too much information for her to handle, and by the end of the year stated, “now I think we are going to slow!” I used an informal reflective formative written assessment to gauge their comfort level with inquiry many times through the year. This written reflection revealed more and more students showed that they actually to enjoyed the process.

#### VALUE

This has been a year of great transition for my students and me. Even though I started to train the students last year while they were in seventh grade in the use of inquiry, the in-depth training this year left many students frustrated and confused. Students were used to following step-by-step instructions, then filling out questions at the end of the worksheet. At the beginning of the year, I was just as frustrated as my

students, but as the school year progressed, I learned as much about the use of inquiry as my students. By the end of the year, I realized that while this transition was difficult to implement, it drastically changed how my students viewed themselves and their ability to answer their own questions.

The first time I ran an inquiry lab resulted in a classroom management disaster. Students thought that since they did not have a defined set of project instructions that they could talk and quickly finish a low quality, simple project. I was frustrated to implement the change from worksheets and videos to inquiry, and I almost stopped the transition.

However, after I implemented formative assessment, classroom structure, and peer-review, the inquiry process improved greatly and classroom management became easier. When I first began peer-review, some students pushed back and some even asked why I wasted their time. I explained that it was a necessary step that ultimately helped them become better writers and thinkers because they were not alone in the problem-solving process. By the end of the year students looked forward to reading what others wrote and liked when their peers wrote suggestions to improve their writing.

Students were engaged and excited to learn about the material with the use of inquiry. When the students were allowed to design their own projects, they were excited to gather data and find a solution to their question. While seated with their peers they supported each other and pushed to better their work. This process was difficult to start correctly, but the students enjoyed the changes, and it was good to see that my students were engaged in their learning.

One exemplary example of a student's growth through inquiry is that of an English Language Learner's lab report (Figure 5). This student was a high-functioning ELL, but until this year was not motivated to participate in class or complete assignments. Last year, the student told me a number of times that he just did not want to work in class. I felt that he was insecure in his academic abilities and used his attitude about classwork as a defensive shield. He was assigned a seat at a table of hard-working students who were closer to his ability, but still challenged him to do the work and be successful. It is important to note that the student designed this lab write-up without being told how to do it, he learned the process by watching his peers and looking at their examples.

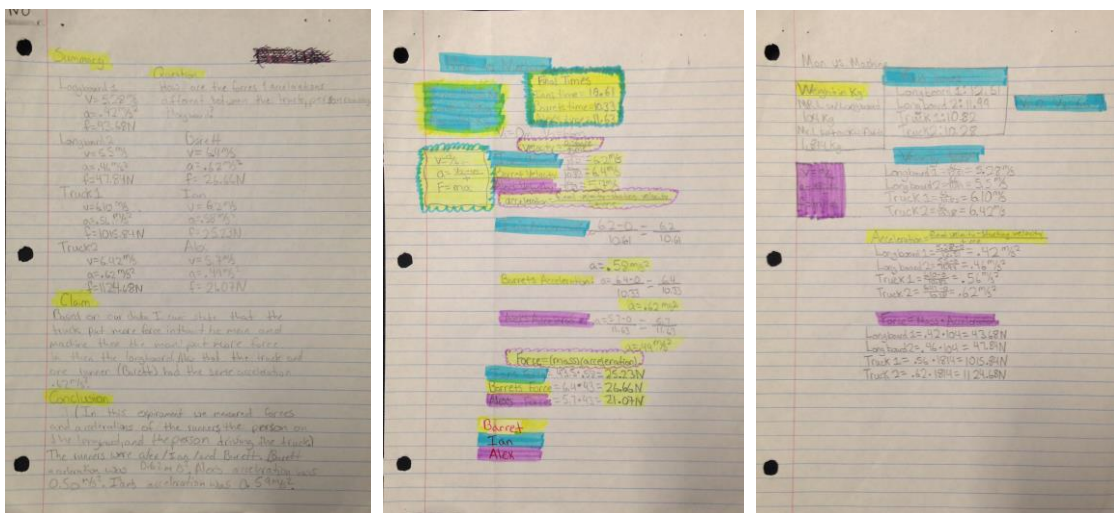


Figure 5. Example of a lab write-up from post-treatment.

At the end of the year, after dealing with the anxiety from students who weren't being told what to do to get the good grade, the students became used to the challenge and began to be empowered in themselves and their decision making process. One student confirmed this by saying, "Open-ended science has been a bit of a struggle for me

just because I really love being told what to do to get a perfect grade and it's been kind of hard to trust my own ideas." I learned that students really do like being asked how they would solve a problem, even though they seemed stressed and anxious during the process. Another student said, "I feel like I've learned a lot from doing all the labs and experiments... Overall I learned a lot more from (investigations) than I would have from doing a worksheet."

If I could do anything differently, it would be to include more engaging activities to connect what we learn in class to the "outside world." Citizen science and field trips would give students a chance to work on real-world science problems, monitor ecological habitats, and help promote stewardship and conservation. I contacted a number of conservation organizations that were excited at the possibility of students aiding their scientists and contributing to their work. I arranged to have students adopt an ecological site on the Boise River. Here, my life science class would establish field study sites to count the number of flora and fauna. The physical science class could monitor the water quality. This field study was supposed to excite the students and aid in their motivation to make a positive change for the environment. Unfortunately, many obstacles including the lack of finance and instruction time halted the field trip.

This project could also be continued through the different academic areas. I had hoped to have the students pick a topic that they could study all year and create their own capstone project. They could collect the data in the science classroom, learn the history in social studies, write about their findings in language arts, and calculate the data in math class. When students learn to ask their own questions and are excited to learn the

answers then anything is possible.

As a teacher I learned that students need to be pushed to achieve amazing academic results. Students were stressed and red-faced with anxiety when I told them they could construct a lab however they wanted. A small group of vocal students started the negativity that spread through the class. I realized after watching the class, most of the students really liked to solve problems on their own. They were insecure about their own abilities and masked their lack of confidence with anxiety and anger towards the assignment. In order to cure their doubt, I began to be their coach instead of their teacher, motivating them to be positive by constantly reassuring their attempts. I was a coach, so I coached, every day, every class, every minute was a reason to push so they would believe in themselves and produce quality work.


This had a dramatic effect on both myself as a person and with my students. By deflecting the negative and reinforcing the positive everyone began to believe in themselves and the process, including myself. Students started to form their own positive culture of learning and supported their efforts, even if they were wrong because they knew how much effort it took to complete the assignments. When I saw this peer reinforcement, I began to feel better about my effort as I was unsure if implementing inquiry in the classroom would actually work. In the end, I learned more about how to be positive with change and my students taught me more than I could ever teach them.

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APPENDICES

APPENDIX A  
INSTITUTIONAL REVIEW BOARD

 <p><b>MONTANA STATE UNIVERSITY</b></p>	<p><b>For the Protection of Human Subjects FWA 0000165</b></p>	<table border="0" style="width: 100%;"> <tr> <td style="width: 50%; vertical-align: top;">           900 Technology Bld., Room 117            c/o Immunology &amp; Infectious Disease            Montana State University            Bozeman, MT 59718            Telephone: 406/994-6783            FAX: 406/994-4329            Email: chern@montana.edu         </td> <td style="width: 50%; vertical-align: top;"> <table border="0" style="width: 100%;"> <tr> <td style="width: 50%; vertical-align: top;">               Chair                Mark Quinn                406-994-5721                mquinn@montana.edu             </td> <td style="width: 50%; vertical-align: top;">               Administrator                Cheryl Johnson                406-994-6783                cheryl@montana.edu             </td> </tr> </table> </td> </tr> </table>	900 Technology Bld., Room 117 c/o Immunology & Infectious Disease Montana State University Bozeman, MT 59718 Telephone: 406/994-6783 FAX: 406/994-4329 Email: chern@montana.edu	<table border="0" style="width: 100%;"> <tr> <td style="width: 50%; vertical-align: top;">               Chair                Mark Quinn                406-994-5721                mquinn@montana.edu             </td> <td style="width: 50%; vertical-align: top;">               Administrator                Cheryl Johnson                406-994-6783                cheryl@montana.edu             </td> </tr> </table>	Chair Mark Quinn 406-994-5721 mquinn@montana.edu	Administrator Cheryl Johnson 406-994-6783 cheryl@montana.edu
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**MEMORANDUM**

**TO:** Dan Leavell and John Graves

**FROM:** Mark Quinn, Chair *Mark Quinn, Ch*

**DATE:** December 2, 2015

**RE:** "Inquiry in the Classroom Using Inquiry to Increase Understanding and Motivation"  
(DL120215-EX)

The above research, described in your submission of December 2, 2015, 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 investigator in such a manner that the subjects cannot be identified, directly or through identifiers linked to the subjects.

(b) (5) Research and demonstration projects, which are conducted by or subject to the approval of department or agency heads, and which are designed to study, evaluate, or otherwise examine: (i) public benefit or service programs; (ii) procedures for obtaining benefits or services under those programs; (iii) possible changes in or alternatives to those programs or procedures; or (iv) possible changes in methods or levels of payment for benefits or services under those programs.

(b) (6) Taste and food quality evaluation and consumer acceptance studies: (i) if wholesome foods without additives are consumed, or (ii) if a food is consumed that contains a food ingredient at or below the level and for a use found to be safe, or agricultural chemical or environmental contaminant at or below the level found to be safe, by the FDA, or approved by the EPA, or the Food Safety and Inspection Service of the USDA.

Although review by the Institutional Review Board is not required for the above research, the Committee will be glad to review it, if you wish a review and committee approval, please submit 3 copies of the usual application form and it will be processed by expedited review.

APPENDIX B

CONSTRUCTING AN INVESTIGATION SURVEY AND QUESTIONS

Participation in this research is voluntary and has no effect on the student’s grade for this class.

Pre and Post Treatment Attitudes about Constructing an Scientific Investigation

I can use the scientific methodology to create an investigation.	I feel comfortable constructing a testable question.	I know how to collect reliable data from an experiment.	I can name the variables and constants in an investigation.	I know how to collect data in an investigation.	I am confident in making tables, graphs, or other models to display and gain data.
Strongly Agree	Strongly Agree	Strongly Agree	Strongly Agree	Strongly Agree	Strongly Agree
Agree	Agree	Agree	Agree	Agree	Agree
Disagree	Disagree	Disagree	Disagree	Disagree	Disagree
Strongly Disagree	Strongly Disagree	Strongly Disagree	Strongly Disagree	Strongly Disagree	Strongly Disagree
I can construct a model that can create or predict data.	I know how to create a claim from data.	I can write a summary that includes data and any necessary calculations.	I feel comfortable orally summarizing the results of an investigation in front of a class.	I can review another investigation and create an argument from the data, claim, and summary.	I feel confident in creating an entire investigation by myself.
Strongly Agree	Strongly Agree	Strongly Agree	Strongly Agree	Strongly Agree	Strongly Agree
Agree	Agree	Agree	Agree	Agree	Agree
Disagree	Disagree	Disagree	Disagree	Disagree	Disagree
Strongly Disagree	Strongly Disagree	Strongly Disagree	Strongly Disagree	Strongly Disagree	Strongly Disagree

Participation in this research is voluntary and has no effect on the students’ grade for this class.

Interview questions to be conducted pre-treatment and post treatment.

1. What is a science investigation? Is it the same as a science experiment? How are they the same and/or different?

2. Do you feel like you can construct a scientific investigation from scratch? What is the first thing you need to construct an investigation?

3. What is a model? How does constructing a model fit into the science investigation?

4. What does it mean to make a claim? How can you make and support a claim with an investigation?

5. Is there anything else you would like to tell me?

APPENDIX C  
MOTIVATION SURVEY AND QUESTIONS

Participation in this research is voluntary and has no effect on the student's grade for this class.

Strongly Disagree/Disagree/Agree/Strongly Agree

1. If I find the class interesting, I will work harder.
2. If I am given the choice of how to complete my assignments, then I am more likely to complete the work.
3. Grades are less important to me, if I find the class interesting.
4. School would be more motivating if I had more choice over the curriculum in the classes that I take.
5. If I could design my own educational path, I would be more motivated to continue my education.
6. I choose to learn in order to please my teachers and parents.
7. My reason for working hard in school is so that I can get good grades.
8. Peer pressure is a driving force for me to get good grades.
9. I would work harder in school if I was paid to get good grades.
10. I get good grades because I want to be known as a high achieving student.
11. I work hard in my classes.
12. I complete my assignments on time.
13. I do my part in group projects
14. I study for tests.

- A fellow student went to college and found out that they could combine degrees to create a unique degree that interests them. Do you think this is a good or bad idea and why?
- Most teachers will decide in advance what the assignments are going to be and how they want students to complete those assignments. Is this the best way to learn new content? Why or why not?
- If students had more input, in regards to the curriculum, what type of academic activities would they choose to do and why?

Participation in this research is voluntary and has no effect on the student's grade for this class.

Interview questions about source for student motivation. Students can choose one of the claims, combine the claims, or write a claim of their own. These are open-ended questions that should be accompanied with a paragraph explanation about why they chose the claim.

Claim #1

You work hard because of the teacher or parents.

Claim #2

You work hard because the class material is exciting and engaging.

Claim #3

You work hard because you want to earn good grades. Why do you want to earn good grades?

Is there anything else you want to tell me?

APPENDIX D  
PERFORMANCE ASSESSMENT RUBRIC

Participation in this research is voluntary and has no effect on the student's grade for this class.

1) Construct a question to be investigated			
1	2	3	4
Question is too broad or general or is a research question that cannot be tested.	Question can be tested but is vague or generalized.	Question can be tested and is specific but needs to be clarified.	Question is testable, specific, and clear to understand.
2) Develops a plan and procedure to complete the investigation.			
1	2	3	4
The investigation lacks a plan or procedure.	The investigation has either a written plan or procedure but lacks the other. Plan or procedure is incomplete.	Plan and procedure are in place but lacks detail so investigation can be replicated by someone else.	The investigation has a detailed plan and procedure so that the study can be replicated by another student.
3) The investigation contains accurate and reliable instruments and methodology for collecting data.			
1	2	3	4
The investigation lacks instruments or methodology to collect data.	The investigation has methods to collect data but they are inadequate to collect reliable data.	The methodology and instruments are adequate to collect data but the student has not collected enough data to construct a claim.	The methodology and instruments are adequate and the student has collected enough data to accurately construct a claim.
4) Display the data.			
1	2	3	4
The investigation did not use any methods to display the data obtained.	The data is only displayed with in a data table.	The data is displayed but the graph, calculations, and/or pictures are incorrect.	The data is displayed with the correct graphs, calculations, and/or drawings.
5) Construct a claim			
1	2	3	4

The investigation lacks a claim.	The claim is not backed by data collected during the investigation.	The claim is backed by data but is confusing or unclear.	The claim is backed by data obtained from the investigation it is clear and efficient.
6) Summary			
1	2	3	4
The investigation lacks a summary.	The summary does not include any data from the investigation.	The summary is present with some data but lacks understanding or rambles about the investigation.	The summary is concise, efficient, and includes the necessary data from the investigation and supporting evidence from the claim.

Participation in this research is voluntary and has no effect on the student's grade for this class.