# THE MYTHBUSTERS PROJECT:

# EFFECTS OF A TERM-LONG INQUIRY BASED SCIENCE PROJECT ON HIGH SCHOOL STUDENT UNDERSTANDING AND ATTITUDES TOWARDS SCIENCE

by

Jason R. Getz

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## STATEMENT OF PERMISSION TO USE

In presenting this professional paper in partial fulfillment of the requirements for a master's degree at Montana State University, I agree that the MSSE Program shall make it available to burrowers under rules of the program.

Jason Ryan Getz

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# TABLE OF CONTENTS

# LIST OF TABLES

# LIST OF FIGURES

# ABSTRACT

Too many high school students go through a chemistry class without really understanding what it is like to conduct authentic scientific research. This investigation sought to determine if a term-long, inquiry-based science project modeled after the Discovery Channel show *MythBusters* affects student understanding of scientific lab processes, student attitudes towards science, and overall understanding of the nature of science (NOS). Students were interviewed, surveyed, observed, and graded over twelve weeks of designing an experiment, carrying out the experiment, and presenting their findings to a group of their peers. At the conclusion of the research, students demonstrated much improved skills, self-confidence, and understanding in carrying out scientific research. In addition, they learned to collaborate well with others, maintained and built upon favorable attitudes and interest towards science, but did not significantly improve upon their understanding of the nature of science.

# INTRODUCTION AND BACKGROUND

## Background and Demographics

For the past four years, I have been a teacher at the Woodberry Forest School in Woodberry Forest, Virginia. It is a boarding school for high school boys. The total student population of our school is 401. Each day is regimented. Nearly every minute of the day is precisely laid out as to where the student needs to be. It is a school built on tradition, which gives it that *southern charm* but also resists progressive change. The students are primarily from affluent Caucasian families from the South, but our admissions department has been working hard to increase diversity as we have students from 26 states and 15 countries (H. Stuart, personal communication, April 1, 2012). We look for the well-rounded student to come to Woodberry Forest. He needs to have interest in playing sports or a musical instrument as everyone is required to have an afternoon activity. In addition, a Woodberry student needs to be academically stronger than average. The pace of the academic day is fast and the time given for study outside of class is slim.

## Origins and Purpose of Study

I am one of several chemistry teachers of sophomores and, therefore, required to teach a curriculum using a standard textbook. However, I chose to supplement this learning using a MythBusters experiment to increase student knowledge related to the nature of science. I chose my topic after observing the positive effect the project had on my classes while teaching at the Pomfret School in Pomfret, Connecticut. The project was developed with my mentor teacher, Sharon Geyer, while at that school. At Pomfret, a final is not given at the conclusion of the winter trimester. Instead, teachers were tasked with having their students work on a project, a paper, or even a presentation of a topic as a final assessment of the winter term. Sharon and I were avid watchers of the MythBusters show and were surprised to learn many of our students were also fans. Thus, the project was born. We put the students through a multi-phased project in which they would test ideas using the scientific method and present their findings at the conclusion of the term.

The MythBusters television show, intentional or not, has had a profound impact on science education. This was evident when Adam and Jamie accepted a White House invitation by President Obama in order to launch his 2010 “Educate to Innovate” event to begin a campaign for science, technology, engineering and math (STEM) (Staedter, 2010). Even President Obama has appeared in an episode to promote science education (Staedter, 2010). In fact, the Discovery website for education has a whole section on scientific inquiry in the classroom, in which the MythBusters are prominently displayed (MythBusters, 2012). The MythBusters utilize the scientific method and design experiments to either support or *bust* common myths or folklore about physical science.

MythBuster Adam Savage would love to see more science students get their hands dirty and learn science by doing experiments (Savage, 2008). In fact, Mr. Savage isn’t alone in endorsing the value of science experiments. In the current state of affairs, a study by Cavicchi and Hughes-McDonnell (2001) found that most teachers have never been involved in an investigation that was something of their own design. When teachers in this study were made to conduct their own investigation they found that the experience made them more aware of what their students were missing out on with traditional structured lab work (Cavicchi & Hughes-McDonnell, 2001). In other words, it changed the way teachers imagined their classrooms. Coursework that successfully engages students in authentic scientific inquiry would see students becoming involved in open-ended problem-solving (Hume & Coll, 2008). In which case, they would use their current conceptual knowledge of science to identify a problem, analyze it, develop a plan, carry it out, collect data, interpret the data to reach a conclusion, and ultimately communicate their findings to others. The MythBusters project sought to accomplish the goals above by actively engaging the students in a hands-on project of their own design.

### Focus Statement

The purpose of this study was to determine how a term-long, inquiry-based science project modeled after the Discovery Channel show *MythBusters* affects student understanding of scientific lab processes, student attitudes towards science, and overall understanding of the nature of science (NOS).

## CONCEPTUAL FRAMEWORK

Since the creation of the No Child Left Behind legislation in 2001, the United States has utilized standard summative assessments to track student achievement as well as the teacher's effect on the class (Blanchard et al., 2010; Jones, Jones, & Hargrove, 2003). Because funding is often tied to these test results, many teachers have stated that the high pressure environment of standard assessment impacts the quality of their teaching as they feel the best thing to do is teach to the test. The intention of the assessments may have been to boost student achievement but the reality has become that the primary goal of these assessments is no longer about student learning or the nature of the teaching. Instead, it has become a system of enticements and penalties, where schools that show steady improvement and growth are rewarded, and schools that do not improve nor change lose funding (Blanchard et al., 2010; Jones et al., 2003).

Moving in parallel with standard assessment testing has been the promotion of inquiry-based education for science classes (Blanchard et al., 2010). The National Science Education Standards (NSES) and other national reform documents market inquiry-based education as a creative and effective way of helping students not only learn science, but also gain an appreciation for the nature of science through inquiry (Blanchard et al., 2010; Llewellyn, 2005; National Research Council (NRC) 1996, 2000). Valid arguments exist for students needing to understand the nature of science (NOS) in order to be considered scientifically literate, which is necessary for citizens of any country to be able to logically participate in controversial socioscientific debates (Trefil, 2008; Vhurumuku, Holtman, Mikalsen, & Kolsto, 2006). Despite many favorable studies that conclude scientific inquiry will help teachers aid their students in gaining an appreciation and understanding of the NOS, become scientifically literate citizens, and achieve higher results on the state exams, there are not many teachers using it in the classroom. In fact, an international survey of chemistry teachers found that in the United States, 45.5% of 571 high school chemistry teachers have never provided their students a chance to create experimental procedures (Cheung, 2008). Furthermore, another study found that only 2% of the observed 9-12 grade classroom lessons put an emphasis on scientific inquiry and only 18% of the classroom lessons utilized math and science as an investigative process in the United States (Rushton, Lotter, & Singer, 2010). Science teachers realize the limitations of traditional lab activities. Students read and follow a stepwise procedure to complete an experiment with a predetermined answer. Because students are working towards completion of the lab, they usually do not have a conceptual understanding of the experimental process (Cacciatore & Sevian, 2009; Cheung, 2008; Rushton et al., 2010). Compounding the problem, many science teachers and administrators are convinced that inquiry-based education cannot be implemented given the current state of affairs with high stakes testing and accountability (Blanchard et al., 2010).

The push for scientific inquiry to be implemented in the classrooms is based upon the assumption that by *doing* science students will learn the scientific process without direct instruction (Bell, Blair, Lederman, Norman, & Crawford, 2003; Cavicchi & Hughes-McDonnell, 2001; Hume & Coll, 2008). Scientific inquiry is the term given to the different methods that exist when it comes to studying the natural world, introducing ideas, and collecting evidence to justify claims and proposals (Vhurumuku et al., 2006). In addition, using scientific inquiry as an approach to teaching science has been nationally researched by the NRC and states that teachers should focus on inquiry when teaching students because it can lead to authentic questions brought about by the student's experiences which are the main idea behind teaching science (Blanchard et al., 2010; Crawford, 2000; NRC, 1996).

Many papers have been written on what scientific inquiry looks like in the classroom. One such example is based upon the four-level framework as described by Blanchard et al. (2010), Llewellyn (2005), Moore (2011), and Smithenry (2010) (Table

1). Level one, verification or confirmation inquiry begins with a teacher asking the questions for the students and then they follow a procedure step by step in order to demonstrate the answers to questions they already knew. In level two, structured inquiry, a question and procedure are again given to the students, but this time they don't know the answer before they begin. Guided inquiry, or the third level, provides the question the students must answer but the method of the investigation and communication of the findings are left entirely to the students. In the final level, open inquiry, students are confronted with developing their own testable questions and develop a method to answer the question they do not know the answer to. The method that works best is dependent on the needs of the classroom. Verification and structured inquiries are quite common in most U.S. chemistry classrooms and are usually referred to as *cook-book* labs as they provided detailed, recipe-like, procedures to follow (Blanchard et al., 2010; Llewellyn, 2005; Smithenry, 2010).

Table 1
*Four Levels of Inquiry (Adapted from Moore, 2011)*

| Inquiry Level | Name | Description | Example |
|---|---|---|---|
| 1 | Confirmation, or *Cookbook* | Student follows step-by-step instructions to confirm a concept. | In this lab you will validate concepts already learned about pH. Follow the procedure below and record your data in the tables provided. |
| 2 | Structured Inquiry | Student follows step-by-step instructions to investigate a concept NOT yet learned. | In this lab, you will determine the relationship between Hydrogen ions and pH by following the procedure below and recording your data in the tables provided. |
| 3 | Guided Inquiry | Students investigate a teacher-generated question creating their own procedures and data. | Design an investigation to answer the question: 'What effect will concentration have on pH of a solution?' Develop a hypothesis, determine a procedure, collect data, and present your conclusion based on that data. Your procedure must be approved before implementation. |
| 4 | Open Inquiry | Students determine their own question and design the procedure to answer it. | Design an investigation to explore a chemistry topic or answer a chemistry question related to what we have been studying. Your procedure must be approved before starting. |

Due to the nature of cook-book style lab exercises, today's science classrooms have little in common with what is actually done by scientists (Hume & Coll, 2008). In order to get the students to want to conduct investigations guided by the teacher, the focus has to be authentic and relatable to the real world. Authentic investigation means creating environments representative of those faced by professional scientists (Crawford, 2000; Windschitl, Thompson, & Braaten, 2008). "Genuine investigation combines eye, heart, hand, and mind as we interact with the world, trying to make sense of what we feel, find, make and think" (Cavicchi & Hughes-McDonnell, 2001, p.2). Direct experimental testing, generating and revising ideas, and interpreting new evidence are all a part of how scientists develop an understanding of our world and it is the investigative process that imitates the view of guided or open inquiry. When implementing these levels of inquiry, it is common for teachers to provide in-class science projects or direct work with scientists outside of class (Bell et al., 2003). It seems logical that if students are actively engaged in science inquiry, they will learn and understand the subject by doing. Yet, obstacles must be overcome in order to implement this style of learning.

The promotion of scientific inquiry-based education has not, as of yet, translated into mainstream use in the classroom (Blanchard et al., 2010). This disconnect mostly has to do with the problem that while research says implementing inquiry in the classroom will lead to positive results; limited sources are available that instruct teachers how to use these methods with their students (Cheung, 2008; Smithenry, 2010). Furthermore, professional development opportunities do not often lead to implementation of inquiry (Rushton et al., 2010; Smithenry, 2010). Some of the biggest complaints in comparable literature are lack of time to implement inquiry, teacher training, beliefs, skills, and knowledge of inquiry, followed by a lack of materials that are authentic to the real world (Blanchard et al., 2010; Cheung, 2008; Smithenry, 2010). Even the National Science Education Standards fail to present a clear picture of how inquiry can be successfully integrated into a traditional science class and what that might look like (NRC, 1996, 2000).

Hume and Coll (2008), looked at how students conducted a practical science investigation under guided inquiry, and found that in the era of high stakes testing scientific inquiry was being narrowly applied in order to develop skills in students that allowed teachers to teach to a standardized test. The study also found that the support materials needed to do a better job in helping students in authentic scientific learning, and teachers require greater leeway in designing programs for students' needs. Another study that put high school students in an eight week apprenticeship working alongside professional scientists found that the students developed physical skills necessary to operate scientific equipment but showed little to no change in their understanding of the nature of science or their understanding of scientific inquiry (Bell et al., 2003).

Successful implementation of science based inquiry requires extensive professional training of the teacher (Blanchard et al., 2010; Cavicchi & Hughes-McDonnell, 2001). Being a learner is deep-seated in becoming a teacher (Cavicchi & Hughes-McDonnell, 2001). "By experiencing the complexities of some natural subject as learners, we enhance our sensitivity to student's confusions and questions—and to their need for space to work these out" (Cavicchi & Hughes-McDonnell, 2001, p.13). In many studies, guided inquiry has been specifically pointed out over other forms of inquiry as producing the most effective results in the classroom when compared to traditional methods towards the nature of science (Blanchard et al., 2010; Cheung 2008; Crawford, 2000). In addition to using guided inquiry, teachers who have successfully implemented guided inquiry based projects in their classrooms have addressed a number of concerns. Primarily, the guided inquiry is based in real world problems and the answers are not predictable or known ahead of time (Cheung, 2008, Crawford, 2000).

The teacher and students work closely together and create experimental plans orally so procedures can be made and modified using a consensus approach (Cheung, 2008). Finally, assessment guidelines must be given to the students ahead of time so they know what is expected of them.

Even in a more traditional lecture based class, inquiry-based learning can be used to supplement information gained through lecture and textbook reading. Smithenry (2010) found one inspiring teacher who began teaching an honors section of high school chemistry with traditional structured labs in the first semester. Little by little over the semester, guided inquiry was introduced and nurtured in the students so that by the second semester the labs had become more student oriented with guidance from the teacher. The teacher in the study had one main goal: at the end of the year the class would be able to effectively work and communicate with each other with little assistance from the teacher in order to work towards solving any problem presented to them using guided inquiry. As for that lack of time issue, it was found that the time spent on inquiry can be used in place of time spent on lecture. The time that would have been used in traditional class lecture is now incorporated within the guided inquiry in a manner that now makes it student-run.

Models for inquiry-based learning can be found in a variety of places, including television. The MythBusters television show serves as a template for any scientific operation. The show begins by introducing a myth, or the main research question (Madsen, 2011). They research the myth while forming hypotheses about the situations and variables surrounding the myth. They then create, build, and implement experiments that test their hypotheses. Finally, they analyze the data, draw conclusions, and present those findings to an audience while ultimately tagging the myth with a confirmed, plausible, or busted label. Professor Martin Madsen (2011) of Wabash College came up with a way to provide his non-major physics students with a hands-on approach to the subject by loosely modeling an inquiry class after the show. His approach was to provide students with a theme and each theme would have a number of myth questions for the student groups to choose from. The investigation was then broken down into two parts. First, they did a number of small-scale preliminary experiments and recorded their findings using digital video cameras. The results were analyzed and the groups then scaled up the experiment as part of the second phase of the investigation. The class did six myths involving six different themes in total for the course. Student feedback on the course was tremendously positive, and the professor found that the students had achieved his key goal of understanding the process of science.

In summary, many researchers have reported on the benefits of inquiry-based labs. Likewise, there are many different ways to implement inquiry-based labs within a science classroom. Although many teachers feel shackled to a curriculum that teaches towards a standardized test, recent research suggest it’s not only possible to implement inquiry labs within a standard classroom but that time given to inquiry actually incorporates concepts that would have been taught in lecture into a student run activity.

# METHODOLOGY

## Treatment

My action research took place over three months from December of 2011 to February of 2012. 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. The treatment for this study consisted of 38 students that were placed into small lab groups in which the students were tasked with using various resources to locate a myth they could investigate via experimentation. The twelve-week treatment period was broken down into four subcategories: the myth, the plan, the experiment, and the presentation. During each phase of the project students received a list of expectations, a rubric for how they would be graded, and examples of previous years' work. After each group had proposed a myth and the teacher approved it, students were left to explore and develop their experiments within their groups.

## Pilot Study

Prior to the beginning of the action research project, a pilot study was conducted with regular chemistry students during the 2011 winter trimester. During this study, data collection tools were created that informed the development of my action research project. A select focus group of 16 students participated in a semi-structured interview and given the Pilot Study Interview Questions (Appendix A). The data were analyzed in order to determine the students' understanding, knowledge, and confidence or apprehensions before attempting a term long science project.

## Pre-Treatment

Students were given a Self-Confidence Survey to determine current skills, laboratory and science project experience, as well as interest in science (Appendix B). The Misconception Probe, which is a type of questionnaire, was also administered in order to determine the students' current understanding of the NOS (Appendix C). Finally a group of 10 students volunteered to participate in answering the Pre-Project Interview Questions (Appendix D). These provided an explanation of the student responses to the Self-Confidence Survey, Misconception Probe, and preconceptions of the NOS and the scientific process.

## The Myth

The first part of the MythBusters project tasked the students with finding a testable myth. The myth could be located by a variety of methods, including internet searches, advertising claims, tales told by other people, ideas proposed or attempted by the MythBusters themselves. I was not worried about whether the students knew the myth to be true as the intended purpose was to design an experiment from a testable statement. However, originality was always encouraged. Each myth that a group proposed to test had to meet some basic criteria including association with chemistry, testability, and originality. No two groups could test the same myth. The myths were graded according to the Myth Grading Rubric (Appendix E).

As the MythBusters project got underway I kept a journal and used the Teacher Journal Prompts to make direct observations of student behavior and attitudes (Appendix F). A Student Attitude Survey was administered to measure initial enthusiasm and the attitude of the students (Appendix G). Another questionnaire, the NOS Questionnaire, was also administered at this time to assess the student's understanding of the lab process (Appendix H). Furthermore, students were given the Participation Survey in order to ascertain how much they thought they had participated in the MythBusters project along with how much work they perceived their partners were putting in (Appendix I).

## The Plan

The second part of the MythBusters project tasked students with creating an experimental plan for their chosen myth. During this phase of the project, the groups were responsible for researching the myth and providing an appropriate description of the expected scientific result. They needed to identify variables and controls as well as list all the materials needed, create a numbered and detailed procedure, and create charts or tables for the data that they were expecting to collect. Each group was provided with the MythBusters Plan Rubric for this part of the project for which grades were administered accordingly (Appendix J). During the creation of the plan, I observed each group and took notes on student attitude and involvement. I would provide assistance to all and any group questions, but was conscious not to provide direct answers. Instead I would direct a group where to find their answers. I wanted this to be entirely of their creation with very little input from me. The groups were given a deadline for submission of their rough draft of the plan. I read them over and provided a lot of comments aimed at getting the groups to think about the level of detail they needed in order to think like scientists. I then sat down with each group for a small conference and we went over those comments so the group could properly address them prior to submitting the final draft of the plan. The Student Participation Survey was administered as the plan was completed. The participation and attitude surveys were administered throughout the MythBusters project to see how attitudes and participation had changed.

## The Experiment

The third part of the MythBusters project tasked students with conducting the experiment for their chosen myth. During this phase of the MythBusters project, students were given three weeks in which they needed to have completed three trials and organized the data into charts, tables, and graphs. Observations were both written in a lab notebook and recorded with photographs taken by me. Students also took pictures of their experimental results and of themselves doing the experiment. At the end of three weeks, the groups submitted their results in a data analysis paper and it was graded according to the MythBusters Experiment Rubric (Appendix K). During the experimentation phase, I was present for each project that involved chemicals, potentially dangerous reactions, or any safety requirements whatsoever. This also gave me the opportunity to see the progress of each project, which I kept track of in my journal along with general reflection of the students' focus, knowledge, and attitude. The Student Attitude Survey was given one week into the experiment phase to ascertain data on student attitudes at the midway portion of the MythBusters project. Again, the Student Participation Survey was administered as the experiment was completed.

## The Presentation

In the fourth and final part of the MythBusters project, students were tasked with presenting the data on a science board poster as well as presenting their findings to an audience of their peers. During the presentation the student groups were expected to determine if their myth was confirmed, plausible, or busted and back that conclusion up with experimental evidence. The presentation of data on both the poster board and to an audience had to stand up to questioning. The MythBusters Poster Rubric and the MythBusters Presentation Rubric were given to the students at the beginning of this phase of the project (Appendices L-M). The poster was due before the presentation was to begin. A variety of components from the plan and the experiment needed to be displayed on this poster. These included: the myth, variables, data tables, charts and graphs, procedure, background research, photographs, data analysis and determination if the myth was confirmed, plausible, or busted. The students then put together a five to ten minute PowerPoint presentation that explained their experimental findings. The Student Participation Survey and the Student Attitude Survey were administered for the final time as the presentations were completed. In addition, the NOS Questionnaire was given to the students a second time to determine if student understanding of the NOS and lab processes had changed as the MythBusters project concluded.

## Post-treatment

Upon completion of the MythBusters project, the same Self-Confidence Survey (Appendix B) along with the Post-Project Interview Questions (Appendix A) was administered. The pre- and post-treatment surveys, questionnaires, and interviews were compared to determine changes in student attitude and understanding over the course of the project. Four of the ten students who were involved in the pre-interview were able to participate in the post project interview. Pre-treatment and post-treatment final grade reports were compared using the Student Grade Comparison sheet (Appendix N). The grades were analyzed for changes in student achievement and understanding of the lab process when the MythBusters project.

In addition, 25 chemistry students in a colleague's class were available to take a Self-Confidence Survey and a Student Attitude Survey. A communication issue prevented the obtainment of this data until near the end of the treatment. This nontreatment student data was compared to the treatment student data. It was analyzed to discern if there was a difference in attitudes and self-confidence in science between students who had completed the MythBusters project and those that did not. The data collection methods are summarized in the matrix below (Table 2).

Table 2
*Data Collection Methods Matrix*

| Research Questions | Data Source 1 | Data Source 2 | Data Source 3 | Data Source 4 |
|---|---|---|---|---|
| Student understanding of lab process | Misconception Probe | Surveys | Pre and Post Interviews | Grades from Rubrics |
| Attitude towards science | Surveys | Teacher Journal Observations | Pre and Post Interviews | Grade comparison of project vs. final exams |
| Overall understanding of the 'nature of science' | NOS Questionnaire | Pre and Post Interviews | | |

## DATA AND ANALYSIS

Prior to the beginning of the treatment, a pilot study with a select focus group of 16 students participated in a semi-structured interview. The data were analyzed in order to determine the students' understanding, knowledge, and confidence or apprehensions before attempting a term long science project. During the action research project, data from the treatment classes were compared, along with the one set of nontreatment data obtained after the treatment period. Data was analyzed in order to determine the effects of the MythBusters project on student understanding of lab processes, NOS, and overall attitudes towards science. Treatment classes had as many as 38 volunteers and nontreatment classes had 25 volunteers. Analyzing the data from the pre and post assessments presented me with four themes. They include: gaining a greater appreciation of lab processes and the scientific method, learning to collaborate with others, general enjoyment doing science, and no significant change in understanding of NOS.

## Pilot Study

The pilot study addressed using the scientific method and the NOS based on the example set forth by the MythBusters television show. At the conclusion of the study, 16 student volunteers were interviewed. During the interview, 100% of the students interviewed believed the project was very time consuming, but each felt he would be comfortable starting a new project from scratch (Figure 1). One student exclaimed doing this project was a lot harder than taking an exam. Another said, "There is a lot more to this project than meets the eye. It's very time consuming." Yet another mentioned, "It's not the experimental testing that takes forever, it's the preparation in getting ready for [experimental] testing." In fact, two of the three primary themes identified in this interview led to my focus question for this research. Those themes included learning the scientific method, learning to apply knowledge, and working on a science project in place of an exam. When asked how this project compared to class, a well-considered response was, “We didn’t learn about balancing equations or stuff like that, but we learned how to graph, experiment, and teamwork.” Another student was able to think outside the classroom about relationships to the world. “When you first think about science you think about boring equations and chemicals and stuff but you don’t really think about how it relates to the world until you start experimenting with something you’re interested in and come to realize there is science backing it up. I mean we proved a multi-million dollar corporation is wrong [referring to the pseudoscience behind Power Bands].” The data collection techniques utilized during this pilot study were aligned with the methodology used for this action research project.

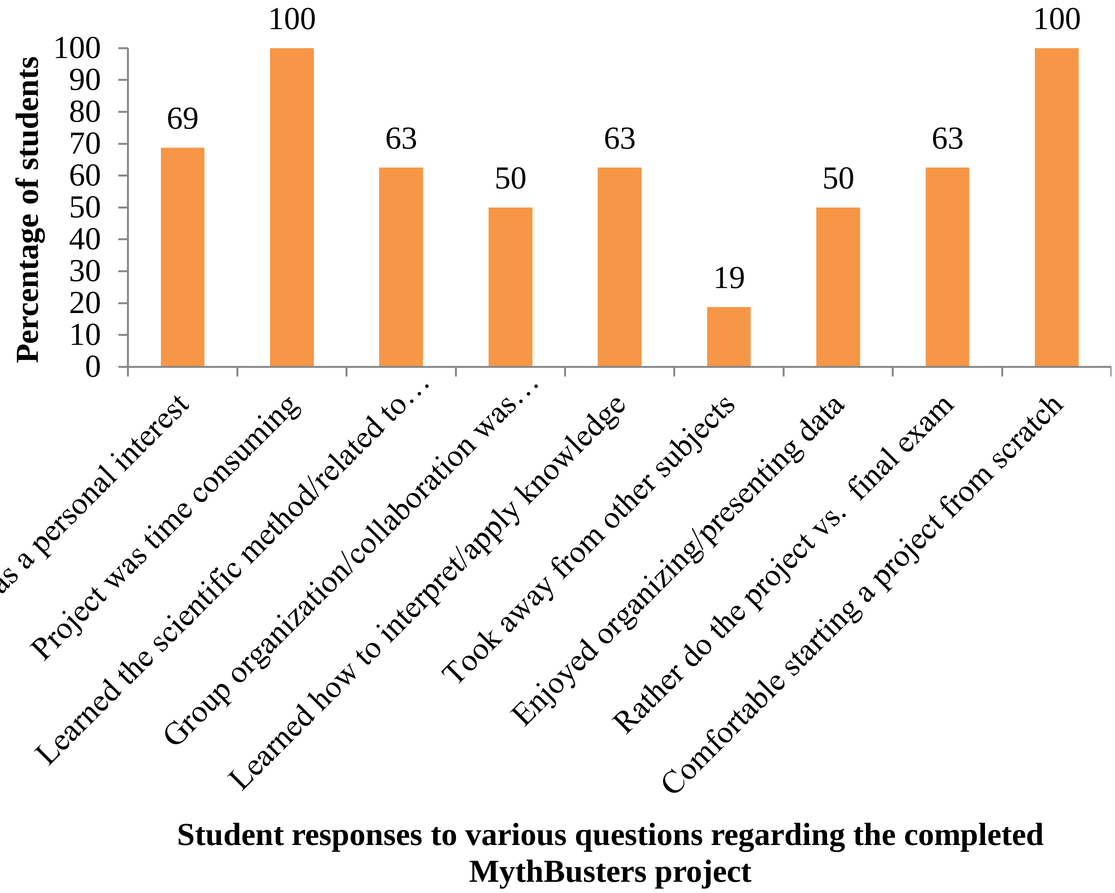


*Figure 1*. Student responses to an interview in which a number of themes were found after the completion of science projects modeled after the Discovery Channel's MythBusters, (*N* = 16).

Appreciation of Lab Processes

Before the MythBusters project began students were presented with a misconception probe in which they were tasked with identifying the most testable statement (Figure 2). Thirty-two students (*N* = 33) correctly identified the first statement as being the one statement out of three that could be tested by current scientific means. Only one student identified the second statement on teleportation as being testable by current scientific means. In regards to the majority response, the results can be further broken down via student explanations. Fourteen students provided a scientific approach in order to test the statement of eating a poppy seed muffin will cause you to fail a drug test. A typical response to this statement was, "It's testable because we can eat poppy seed muffins and take a drug test." Another student invoked the scientific method when he stated, "It's testable because it is able to be tested by the scientific method; teleportation probably is the fastest but does not exist, and no experiment should involve having to die and go to Hades." Furthermore, one student went as far as to mention an experimental control when he said, "You could have someone take a drug test without having eaten a poppy seed muffin and then take one [drug test] having ate them." Nine students implied experimentation but failed to provide much detail. For example, a simple response from one student that was echoed by others was, "We have the current technology and ability to test it." Another response that was shared by some other students can be summed up as, "The other two cannot be tested because teleportation does not exist and you cannot test death." Another nine students either provided no response or the comments indicated no real explanation. In contrast, the lone student who chose the statement, the fastest way to get from Albuquerque to Timbuktu is via teleportation, had this to say in defense, "Straight line is the fastest way between two points."

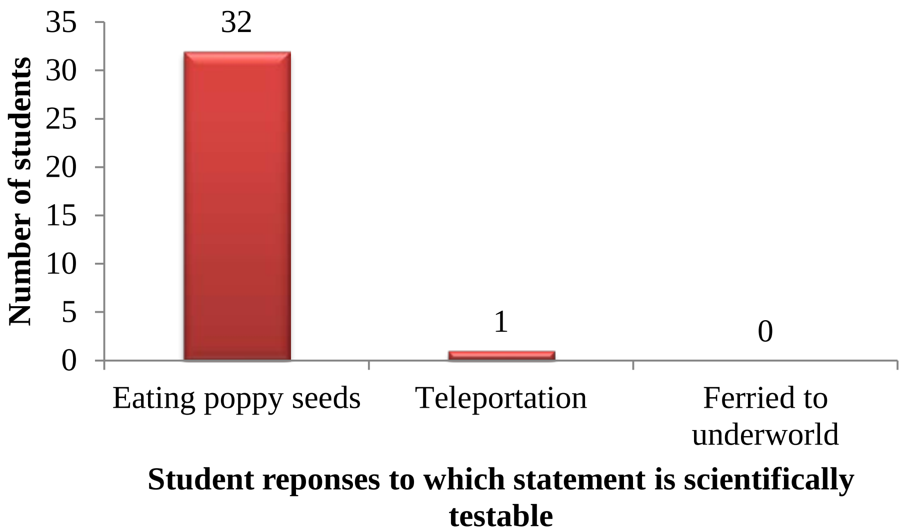


*Figure 2*. Student responses to a misconception probe asking them to identify the most scientifically testable statement, (*N* = 33).

The results of pre (*N* = 34) and post treatment (*N* = 35) self-confidence surveys provided insight into lab process knowledge gained upon completing the MythBusters project. Table 3 depicts the changes in confidence for each question on the survey. Among the *very* confident students, there are observed positive changes in six of the eight categories. In contrast, there are fewer *not very* and *not at all* confident students with five of the eight *not very* categories reporting negative differences in percent values. In addition, one of the *not at all* confident categories had students report negative differences in percentages from before and after the project. The data is indicative of a majority group of students now confident in their abilities to apply the scientific method towards a research topic.

Table 3
*Differences in the Percentages of Pretreatment (N=34) and Post treatment (N=35) Student Self-Confidence.*

| | Very | | | Somewhat | | | Not Very | | | Not at All | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Pre | Post | D% | Pre | Post | D% | Pre | Post | D% | Pre | Post | D% |
| Creating a research topic | 40 | 59 | 19 | 60 | 41 | -19 | 0 | 0 | 0 | 0 | 0 | 0 |
| Designing an experiment | 40 | 60 | 20 | 46 | 40 | -6 | 14 | 0 | -14 | 0 | 0 | 0 |
| Taking accurate measurements | 71 | 68 | -3 | 23 | 29 | 6 | 6 | 3 | -3 | 0 | 0 | 0 |
| Using Graphs and Charts Software | 34 | 35 | 1 | 43 | 50 | 7 | 23 | 15 | -8 | 0 | 0 | 0 |
| Using Power Point | 54 | 74 | 20 | 43 | 24 | -19 | 3 | 0 | -3 | 0 | 3 | 3 |
| Writing a scientific paper | 29 | 44 | 15 | 60 | 53 | -7 | 9 | 0 | -9 | 3 | 3 | 0 |
| Will increase interest in science | 31 | 53 | 22 | 49 | 38 | -11 | 17 | 9 | -8 | 3 | 0 | -3 |
| Will increase desire for science in college | 6 | 32 | 26 | 37 | 44 | 7 | 46 | 21 | -25 | 11 | 3 | -8 |

*Note.* D% = Differences in Percent Values.

The results of the nontreatment (*N* = 25) and treatment (*N* = 35) self-confidence surveys provided greater insight into lab process knowledge gained upon completing the MythBusters project. Table 4 depicts the differences in confidence for each question on the survey. Among the *very* confident students, there are observed positive differences in seven of the eight categories for the treatment classes versus the nontreatment classes. Also, similar to Table 3, there are much fewer *not very* and *not at all* confident students that have received treatment as six of the eight *not very* categories reported greater than a negative 10% difference in values. In addition, there are only three n*ot at all* confident student response categories that have received treatment as compared to six n*ot at all* confident nontreatment student response categories. This translates to a 50% difference in student responses in these categories or a negative difference in percentages in all six categories that have received a response. This indicates the treated students have much more confidence in conducting a science project with the biggest overall positive difference being found in creating a research topic, designing an experiment, and writing a scientific paper. The biggest overall negative difference in percentages is also found under writing a scientific paper as 36% of the nontreated students reported being *not very* confident as opposed to 0% of the treated students. This greater understanding and confidence in lab processes is also depicted in Figure 3 which shows the average response for each category and question in the self-confidence survey.

Table 4
*Differences in the Percentages of Nontreatment (N=25) and Treatment (N=35) Student Self-Confidence.*

| | Very | | | Somewhat | | | Not Very | | | Not at All | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | NT | T | D% | NT | T | D% | NT | T | D% | NT | T | D% |
| Creating a research topic | 24 | 59 | 35 | 52 | 41 | -11 | 12 | 0 | -12 | 12 | 0 | -12 |
| Designing an experiment | 32 | 60 | 28 | 56 | 40 | -16 | 12 | 0 | -12 | 0 | 0 | 0 |
| Taking accurate measurements | 68 | 68 | 0 | 28 | 29 | 1 | 4 | 3 | -1 | 0 | 0 | 0 |
| Using Graphs and Charts Software | 24 | 35 | 11 | 36 | 50 | 14 | 28 | 15 | -13 | 12 | 0 | -12 |
| Using Power Point | 48 | 74 | 26 | 32 | 24 | -8 | 12 | 0 | -12 | 8 | 3 | -5 |
| Writing a scientific paper | 16 | 44 | 28 | 44 | 53 | 9 | 36 | 0 | -36 | 4 | 3 | -1 |
| Will increase interest in science | 36 | 53 | 17 | 36 | 38 | 2 | 20 | 9 | -11 | 8 | 0 | -8 |
| Will increase desire for science in college | 12 | 32 | 20 | 48 | 44 | -4 | 24 | 21 | -3 | 16 | 3 | -13 |

*Note.* NT = Nontreatment, T=Treatment, D% = Differences in Percent Values.

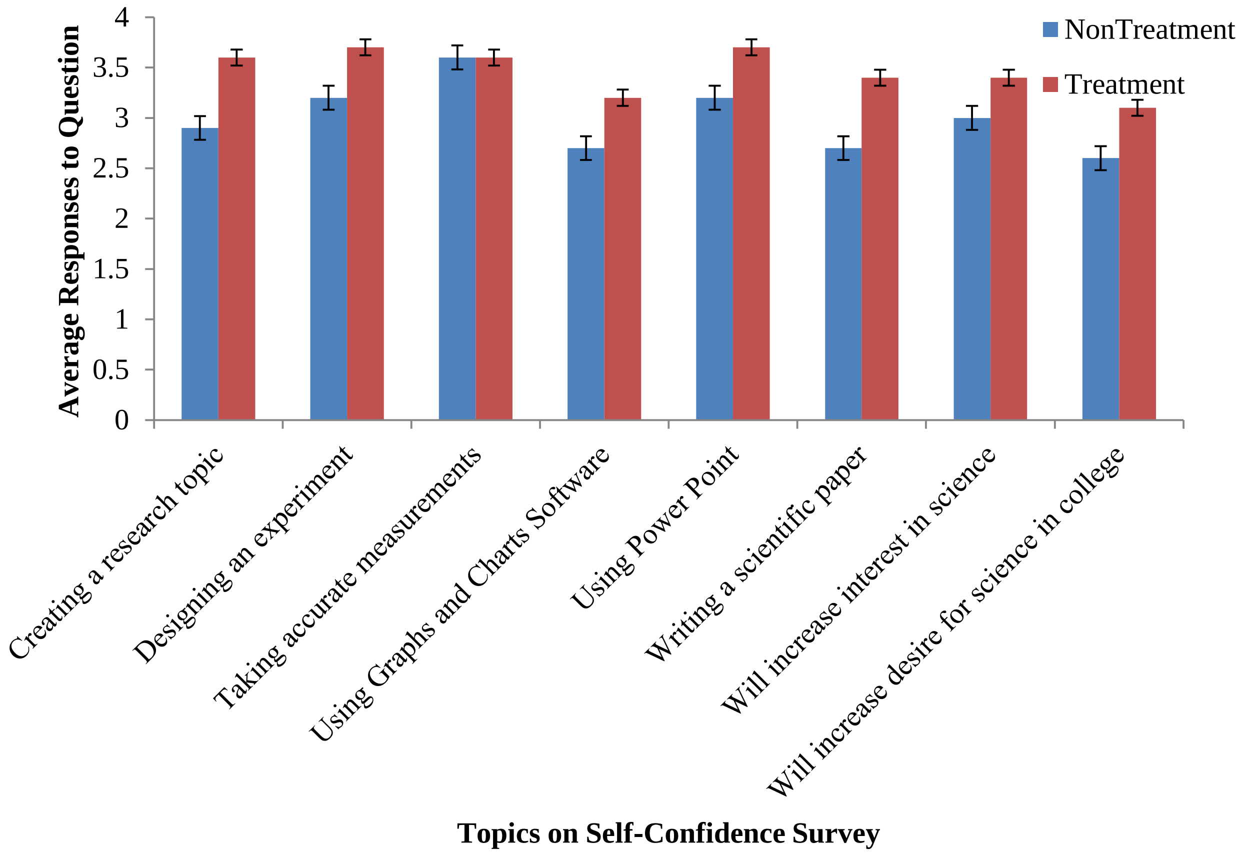


*Figure 3.* Average response of student self-confidence towards scientific research and science for a nontreatment group (*N* = 25) and a treatment group (*N* = *35).*
*Note.* 4 = Very Confident, 3 = Somewhat, 2 = Not Very, 1 = Not at All.

Prior to the treatment, a volunteer group of ten students were interviewed and they indicated they were already familiar with the investigative process of science. They described it as making a hypothesis, designing an experiment, and making a conclusion. One student went as far to say, "Even if you're not writing everything down you're still following it [scientific method]." When asked how they expect the MythBusters project to be different from labs conducted in the classroom, some students were excited because they anticipated controlling their project completely. Some liked the idea of doing something they were interested in, and another was interested in drawing his own conclusions. A student stated, "I think this project is going to challenge ourselves beyond normal labs because we won't get handouts telling us what to focus on." Furthermore, two other students couldn't wait to learn something. The first student said, "I want to gain a better understanding of the procedure making process." The other student added, "I just really want to test one of these and see if it works."

Upon conclusion of the MythBusters project, some of the same students were again interviewed. One student gained an appreciation of the investigative process upon learning how much error could exist in an experiment. His group attempted to control many variables as they were recording the number of basketball shots made in an experiment analyzing the effects of a shooting sleeve on basketball players. Another student learned the value of conducting an experiment as he got results he didn't expect. It prompted him to state, "Google doesn't always work." Using the data he collected, his scientific write up for a movie myth in which strong acid quickly eats through metal chains revealed that Hollywood magic is sometimes just that. Finally, in comparison to normal labs, the MythBusters project helped one student remember things more because, "I did it instead of being told about it."

## Collaboration with Others

Throughout the treatment period, participation was measured for each of the four phases of the MythBusters project by use of a participation survey. Each data set was converted to a percentage and the differences in percent values were calculated between the beginning and end of the project as recognized by the myth and the presentation (Table 5). The data ($N$ = 37) displayed an upward trend as the project progressed. Participation was at its lowest during the beginning of the project as groups were selecting their myths. Specifically, only 49% of the students claimed to have always done their job at the onset of the project. This was an average of 19 out of 37 students ranking themselves lower than a 4.0 which carried an *always* label. In other words, nearly 51% of students were not participating to the fullest in beginning. One student said, “I was ready to help but had other things too.” Another pleaded, “Need a lot more help from my partners.” In fact, student interviews revealed collaborating with group members would be a challenge from the beginning. “One of the harder things will probably be one of the more important things and that is good collaboration amongst each other in the group.”

Table 5
*Differences in Percentages of Student Participation Throughout the MythBusters Project (N = 37)*

| | Always | | | | | Almost Always | | | | | Sometimes | | | | | Never | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | M | Pl | E | Pr | D% | M | Pl | E | Pr | D% | M | Pl | E | Pr | D% | M | Pl | E | Pr | D% |
| Did my job | 49 | 66 | 81 | 84 | 35 | 28 | 29 | 16 | 16 | -12 | 14 | 6 | 3 | 0 | -14 | 0 | 0 | 0 | 0 | 0 |
| Shared info | 59 | 77 | 84 | 89 | 30 | 35 | 23 | 16 | 11 | -24 | 3 | 0 | 0 | 0 | -3 | 3 | 0 | 0 | 0 | -3 |
| Listened | 70 | 86 | 86 | 89 | 19 | 16 | 11 | 11 | 11 | -5 | 11 | 3 | 3 | 0 | -11 | 3 | 0 | 0 | 3 | 0 |
| Cooperated | 81 | 74 | 76 | 78 | -3 | 8 | 20 | 11 | 3 | -5 | 8 | 6 | 11 | 3 | -5 | 3 | 0 | 0 | 3 | 0 |

*Note.* M = Myth, Pl = Plan, E = Experiment, Pr = Presentation, D% = Differences in Percent Values. N = 35 for Plan data.

Doing my job and the sharing information responses had the greatest increase in participation by project’s end. Cooperation within the group had consistently high participation in the *always* category. Listening to others also had an observed 19% increase in the *always* category by project’s end. One student shared, “We all did our part and the work was distributed very evenly.” Another student’s comment summarizes the overall data trend when he said, “My partner’s work was impressive compared to the beginning of the project. He became more active as time went on.”

The average grade for each group (*N* = 38) during the four phases of the MythBusters project appears to be positively associated with group participation (Figure 4). During the selection of the myth, the average grade was an 81% in accordance with the rubric. As the project continued there were increases in overall averages as the plan earned an 87% and then the actual experiments, along with the corresponding scientific paper, earned the highest overall average of a 90%. The project grade data (*N* = 38) can be further broken down into quartiles (Figure 5). The lowest score achieved was a 70% during the myth project phase. Conversely a grade of 100% was also achieved in the myth project phase and again in the poster and presentation phase of the project. An examination of the second quartile shows a systematic improvement in the median scores from the myth phase up through the experiment phase. The slight drop in the presentation phase of the project was due to a number of groups overlooking an important piece of information that needed to be included on their science posters. Figure 6 contains data reflective of improvement of scores within each quartile throughout the project as it progressed from the myth, to the plan, experiment, and presentation (*N* = 38). No group scored lower than an 80% and the median was an 86.5%. In summary, as the participation level within in the groups increased so too did the average grades.

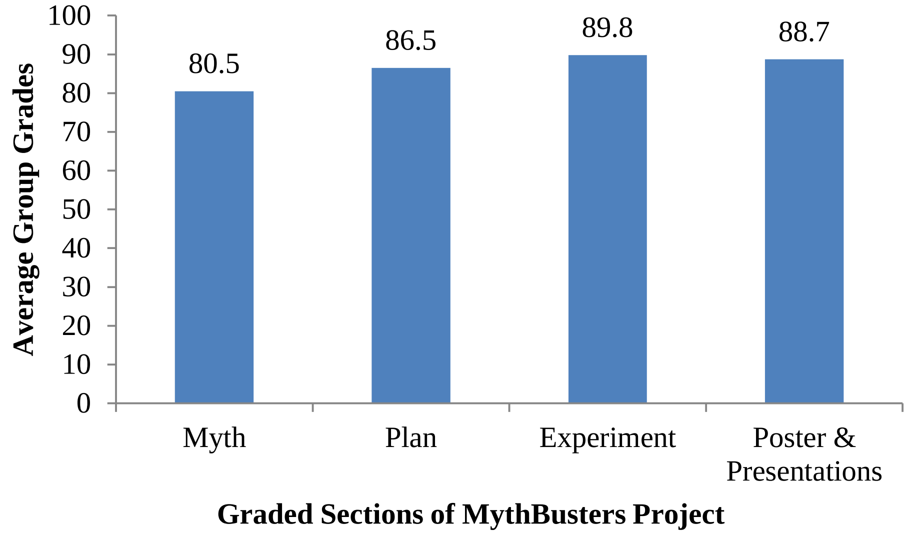


*Figure 4.* Average group grades during MythBusters project sections, (*N* = 38).
*Note.* 90% = A-, 89-87% = B+, 86-83% = B, 82-80% = B-.

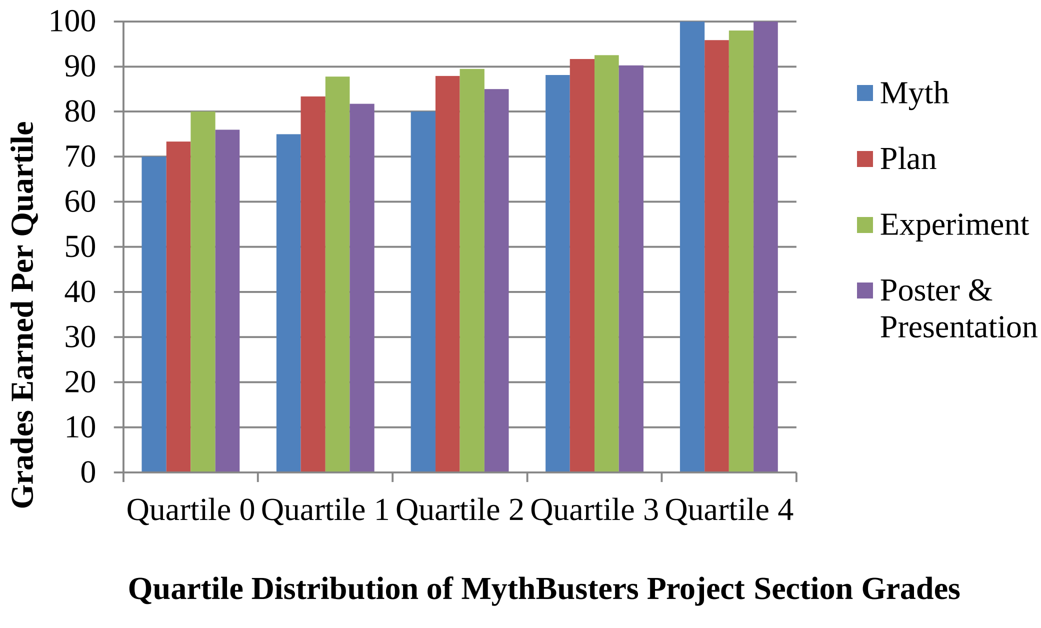


*Figure 5.* Quartile grade distribution during MythBusters project sections, (*N* = 38).
*Note.* 90% = A-, 89-87% = B+, 86-83% = B, 82-80% = B-, 79-77 = C+, 76-73 = C, 72-70 = C-.

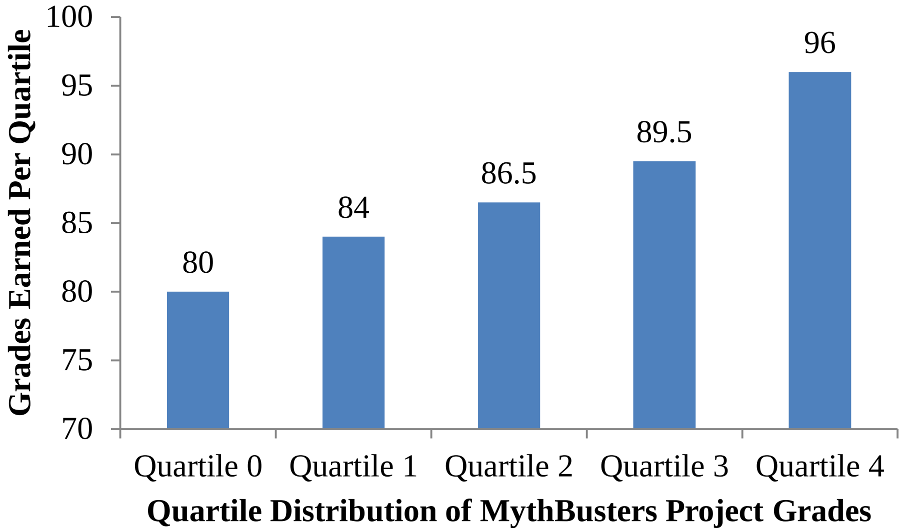


*Figure 6.* Quartile grade distribution for overall MythBusters project scores, ($N$ = 38). *Note.* 90% = A-, 89-87% = B+, 86-83% = B, 82-80% = B-.

Attitudes about Science

Data was collected to determine the overall attitudes students had towards science in both a treatment group and a nontreatment group. During the treatment, the attitude survey was given three times, corresponding with the beginning, middle, and end of MythBusters project (Figure 7). On the survey, the scale ranges from 1 to 7, where a 1 equals *strongly disagree* and a 7 equals *strongly agree*. Attitudes towards science were at its highest in the beginning of the treatment, and though it remained high on average, the data starts slowly trending downward. The differences in percentages amongst the pretreatment ($N$ = 38) and post treatment responses ($N$ = 30) are summarized in Table 6. Many students disagree with statements of: *being told the facts*, *I dislike science*, *science is a waste*, or *science is uninteresting*. The average response for these statements is between 2.2 to 3.5 which means *disagree to somewhat disagree*. A closer look at Table 6 reveals a 14% increase in those disagreeing with being told the facts over doing an experiment. In addition, there is a 9% decrease in students strongly agreeing with *disliking science* corresponding to an 18% increase with those that disagree with the statement. Conversely, many students tend to agree with various statements such as: *doing experiments, science lessons are fun,* and *science is most interesting*. These statements fall within a range of 4.9 to 6.1 which is *somewhat agree to agree.* However, a look at Table 6 reveals a decrease in the number of students who strongly agreed with these statements at the beginning of the project. The data still shows that students agree or somewhat agree with these statements, but doing a research project has seemingly dampened their convictions. For example, there was a 23% decrease in those strongly agreeing with doing experiments versus reading about them. Yet, there was a 9% increase in those agreeing and an 11% increase in those somewhat agreeing. Furthermore, there was a 16% decrease in those agreeing with *science lessons are fun* corresponding with a 16% increase in those somewhat agreeing. Overall, attitudes towards science are favorable within the treatment group.

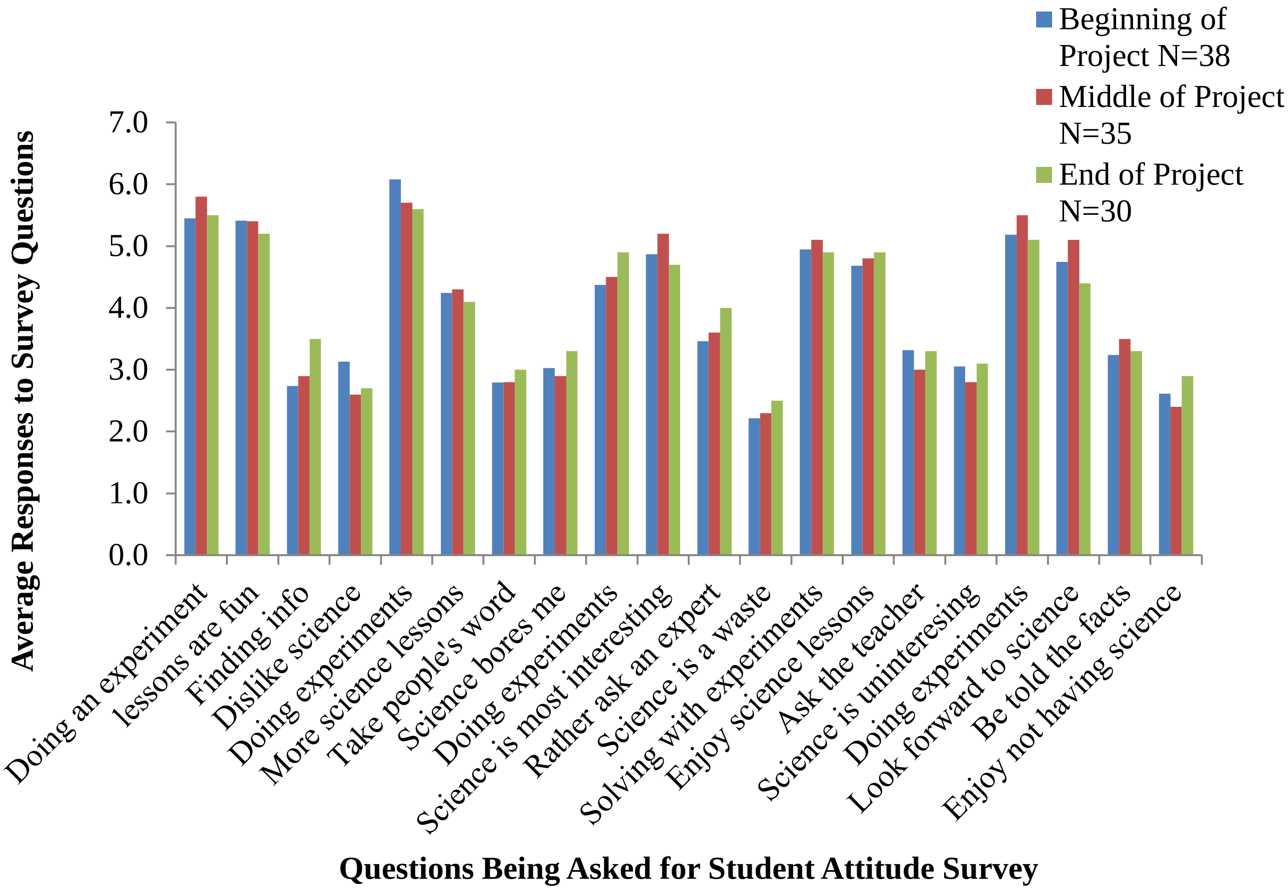


*Figure 7.* Student attitude towards science over the duration of the MythBusters project.
*Note.* 7 = Strongly Agree, 4 = Not sure, 1 = Strongly Disagree.

Table 6
*Differences in the Percentages of Pretreatment (N=38) and Post Treatment (N=30) Student Attitudes Towards Science*

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|
| Doing an experiment | 1 | -3 | -1 | 5 | -7 | 3 | 2 |
| lessons are fun | 0 | 1 | 2 | -3 | 16 | -16 | 0 |
| Finding info | -24 | 9 | -2 | 5 | 2 | 11 | -2 |
| Dislike science | -9 | 18 | 4 | 3 | -9 | 1 | -8 |
| Doing experiments | 1 | 3 | 1 | -1 | 11 | 9 | -23 |
| More science lessons | 4 | 1 | 10 | -21 | 6 | -1 | 1 |
| Take people's word | 1 | 2 | -6 | -5 | -4 | 10 | 1 |
| Science bores me | -6 | 7 | -8 | 4 | 2 | -5 | 7 |
| Doing experiments | -2 | -9 | 5 | -15 | 10 | 9 | 2 |
| Science is most interesting | 1 | -2 | -1 | 1 | 16 | -12 | -3 |
| Rather ask an expert | -12 | -7 | 4 | 6 | 5 | 12 | -8 |
| Science is a waste | -5 | -7 | 8 | -4 | 4 | 3 | 0 |
| Solving with experiments | 1 | -3 | 3 | -8 | 6 | 8 | -7 |
| Enjoy science lessons | 1 | -3 | -3 | -3 | 4 | 5 | -1 |
| Ask the teacher | -12 | -6 | 24 | 4 | -1 | -3 | -5 |
| Science is uninteresing | 4 | -1 | 2 | -9 | 1 | -4 | 7 |
| Doing experiments | -5 | -2 | 5 | 4 | 14 | -10 | -6 |
| Look forward to science | 3 | -9 | 18 | -10 | 12 | -13 | -2 |
| Be told the facts | -14 | 6 | 14 | -2 | 2 | -4 | -2 |
| Enjoy not having science | -11 | -6 | 17 | -1 | 5 | -3 | -1 |

*Note.* 1 = Strongly Disagree, 4 = Not Sure, 7 = Strongly Agree.

The nontreatment group ($N$ = 25) took one attitude survey corresponding with the end of the treatment period. The data was analyzed in several ways. The first involved taking the average responses and comparing them to the average response for the treatment group ($N$ = 30) (Figure 8). The data responses for nontreated and treated groups were also converted to percentages and the differences in percent values were compared per question (Table 7). Finally, the raw data responses were put through a T-Test analysis to determine if any of the responses to the questions were statistically significant (Table 7). The treatment group had more agreement on average than the nontreatment group in the following categories: *science lessons are more fun*, *more science lessons*, *look forward to science*, *rather ask an expert*, *rather ask the teacher*, and *rather be told the facts*. Conversely, the nontreatment group agreed more than the treatment group in the following categories: *I prefer to do experiments over reading, prefer to do my own experiments, I'd rather solve with experiments than be told the answer*, and *science is a waste of time*. A closer look at Table 7 reveals some interesting trends. In the various attitude statements that involve doing an experiment over learning about it or being told, the treatment group is more likely to agree or somewhat agree versus the nontreatment group which tends to strongly agree. For example, the treated group has a 23% decrease in those that strongly agree with they would rather do an experiment over reading about it. This corresponds with a 19% increase in the treated students that somewhat agree with this statement. In addition, there is an 11% increase in those that strongly agree that science lessons are fun. Some insight was provided when a student in the treatment group said, "The project helped me learn about science and shooting [a basketball], but class was better for knowing science than trying to figure it out myself." Another student stated, "With MythBusters, we figured out why it happened!" That student was backed up by another whom stated, "Yeah, we had a better chance to know what's going on." No interview data is available for the nontreatment group.

The T-Test was conducted for two independent samples of unequal variance with one-tail. No p-value is less than 5% so the null hypothesis of no statistical difference between the two surveys is valid. From the T-Test data, four questions had p-values in the 20% to 30% range and, though statistically irrelevant according to the test, they do stand out amongst the other questions. They include: *I'd rather ask an expert than do an experiment*, *I'd prefer to do my own experiments than find out information from a teacher*, *I dislike science,* and *I look forward to science lessons*. Regarding the disliking of science question, there is a 7% increase among the treatment group that strongly disagrees in this category. Yet, there is also a 5% increase among the treated group of students who strongly agree with looking forward to science lessons. In the experiments statement, the treatment group experienced a 9% decrease in strongly agreeing, a 9% increase in somewhat agree, and a 17% increase in somewhat disagree. Similarly, the treatment group experienced a 16% increase in agreeing that they would rather ask an expert and an 18% decrease in strongly disagreeing with this statement versus the nontreatment group. The overall averages display a want of doing science experiments as well as a general enjoyment of science for both the treated and nontreated groups. The percent difference data indicates a stronger desire to want to do experiments among the nontreatment students. The treated students, having been through the MythBusters project, seem to be gaining a better-rounded attitude of science lessons and experiments.

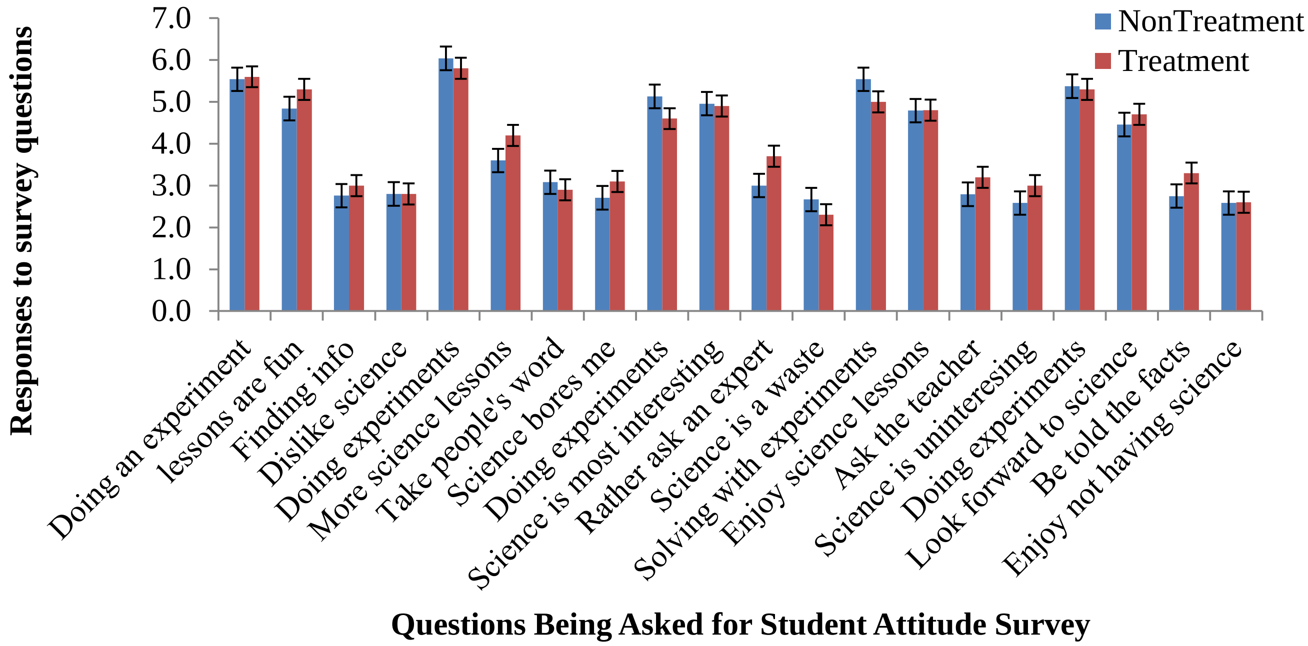


*Figure 8.* Student attitude towards science comparison of treatment ($N$ = 30) versus nontreatment ($N$ = 25) groups.
*Note.* 7 = Strongly Agree, 4 = Not sure, 1 = Strongly Disagree.

Table 7
*Differences in Percentages and T-Test Analysis of the Responses of Nontreatment (N=25) and Treatment (N=30) Student Attitudes Towards Science*

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | p-value |
|---|---|---|---|---|---|---|---|---|
| Doing an experiment | -1 | -4 | 7 | 5 | 0 | -15 | 8 | 0.3328 |
| lessons are fun | -4 | -9 | 3 | 2 | 15 | -18 | 11 | 0.3712 |
| Finding info | -14 | 0 | -6 | 9 | 2 | 6 | 3 | 0.4924 |
| Dislike science | -7 | 13 | 3 | -7 | -1 | -1 | 0 | 0.2116 |
| Doing experiments | 3 | -5 | 3 | -1 | 19 | 3 | -23 | 0.3860 |
| More science lessons | -5 | -13 | 11 | -2 | 0 | 6 | 3 | 0.3184 |
| Take people's word | 7 | -8 | 12 | -7 | -13 | 10 | -1 | 0.3039 |
| Science bores me | -3 | -23 | 6 | 19 | -3 | -4 | 7 | 0.3232 |
| Doing experiments | 3 | -17 | 17 | 4 | 9 | -6 | -9 | 0.2477 |
| Science is most interesting | 3 | -1 | -2 | -8 | 19 | 8 | -19 | 0.3121 |
| Rather ask an expert | -18 | -14 | 11 | 13 | -8 | 16 | 0 | 0.2864 |
| Science is a waste | 1 | -5 | 13 | -7 | 3 | -5 | 0 | 0.3134 |
| Solving with experiments | 7 | 0 | 13 | -15 | 5 | 3 | -13 | 0.3100 |
| Enjoy science lessons | -1 | -4 | 6 | -2 | 1 | -2 | 2 | 0.3072 |
| Ask the teacher | -23 | -1 | 24 | -4 | -3 | 6 | 0 | 0.3045 |
| Science is uninteresing | -9 | -5 | 8 | -6 | 7 | 3 | 3 | 0.3024 |
| Doing experiments | 0 | -5 | 2 | 16 | 9 | -20 | -2 | 0.3071 |
| Look forward to science | -1 | -2 | 11 | -8 | 1 | -7 | 5 | 0.2647 |
| Be told the facts | -14 | -7 | 22 | -13 | 6 | 3 | 3 | 0.3369 |
| Enjoy not having science | 5 | -21 | 8 | 4 | 6 | -8 | 7 | 0.3023 |

*Note.* 1 = Strongly Disagree, 4 = Not Sure, 7 = Strongly Agree.

My own observations were generally quite positive towards the MythBusters project (Figure 9). I took observations during all four phases of the project for a total of seven recorded teacher journal prompts. Each observation was scored and all prompts were averaged together and graphed. My overall attitude scored a 4.4 out of a possible 5.0 on scale where a 5 equals *very positive* and a 1 equals *disappointed*. I felt the students were very engaged throughout the MythBusters project and worked well together in groups. Among my lowest ranking observations were student attitude and desire to learn. This was because at certain points in the trimester students were just not as motivated to do work. For example, during the plan phase I observed, "Students were generally apathetic about getting started. Perhaps this phase is the most daunting or maybe it's because it's the first day after the holiday break." Over the twelve week treatment period I observed some resistance to the project at first, but as it went on there was more group work, more curiosity and desire to learn, and a majority of students got something out of it.

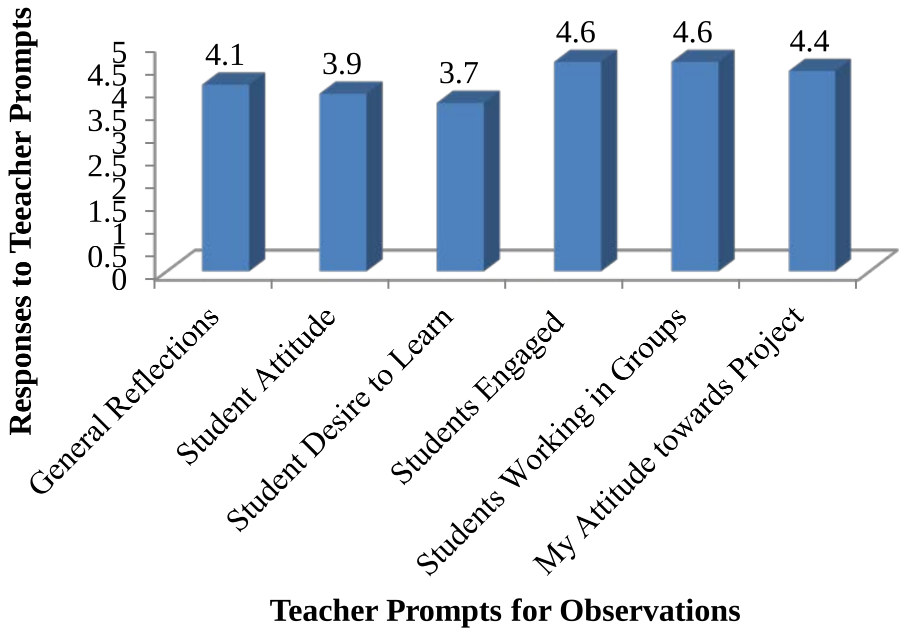


*Figure 9.* Teacher's attitude towards MythBusters project, ($N$ = 1).
*Note.* 5 = Very positive, 3 = Uncertain, 1 = Disappointed.

Perhaps the most telling indicator of student attitude towards the MythBusters project can be found by looking at student self-confidence (Table 3 and Table 4). There is a 22% increase in students in the treated group saying they are *very* confident that the MythBusters project has increased their interest in science. There is a 17% increase when comparing those students in the treatment group versus the nontreatment group.

Even more interesting is the 26% increase in students in the treated group who claim they are now *very* confident they would go to college for science. Compared to the nontreated group, this is a 20% increase in number of individuals who are *very* confident in going to college for science upon completing the MythBusters project.

## No Changes in NOS

Data were collected on the students understanding of NOS both before and after the treatment. Students responded to questions by circling one of five choices. Choices were then tabulated and converted to percentages for each question. NOS was broken down into six categories: observations and inferences, nature of scientific theories, scientific laws vs. scientific theories, social and cultural influence, imagination and creativity, and scientific investigation.

### Observations and Inferences

This category had students determining how a scientist makes observations and interpretations (Table 8). The T-Test values indicate none of the data sets are statistically significant. However, there is a large difference in percent in the post treatment ($N$ = 22) response to *observations are facts* as compared to the pretreatment ($N$ = 15). Those that disagree with that statement increased 19% indicating more students are aware that observations are not facts. In addition, there was a 16% increase of the post treatment students strongly agreeing with *scientists prior knowledge affecting observations*. One student said it best, “Scientists have some of their own ways of doing their work so scientists will make similar observations but they will make slightly different conclusions.”

Table 8

*Differences in Percentages and T-Test Analysis of Student NOS Understanding of Observations and Inferences PreTreatment (N = 15) and Post Treatment (N = 22)*

| | SD | D | U | A | SA | p-value |
|---|---|---|---|---|---|---|
| Scientists observations of the same event may be different because the scientists' prior knowledge may affect their observations | 5 | 0 | -7 | -14 | 16 | 0.3206 |
| Scientists' observations of the same event will be the same because scientists are objective. | 16 | -28 | -11 | 14 | 9 | 0.3458 |
| Scientists' observations of the same event will be the same because observations are facts | 3 | 19 | -8 | -15 | 2 | 0.2191 |
| Scientists may make different interpretations based on the same observations. | 0 | 0 | 16 | -10 | -6 | 0.2384 |

*Note.* SD = Strongly Disagree, D = Disagree, U = Uncertain, A = Agree, SA = Strongly Agree.

Nature of Scientific Theories

Student responses to nature of scientific theories show some real changes in knowledge (Table 9). However, the T-Test values indicate none of the data sets are statistically significant. Students seem to understand that theories are based on many experiments and provide a plausible explanation based on evidence. The data also indicates that students recognize theories can be amended or even discarded. There was a 25% increase in the students post treatment (*N* = 22) compared to pretreatment (*N* = 15) that strongly agree that *theories are subject to ongoing testing and revision*. In fact, the p-value of 11% for the *ongoing testing and revision* statement was the closest probability statistic of all the NOS questions asked in this survey. Furthermore, there was a 32% increase in the students that disagreed with the statement *theories based on accurate experimentation will not be changed*. One student said, “Scientific theories are strong ideas tested by a lot of people, but one single new invention can overwrite it because theories aren't facts."

Table 9
*Differences in Percentages and T-Test Analysis of Student NOS Understanding of the Nature of Scientific Theories Pretreatment (N = 15) and Post Treatment (N = 22)*

| | SD | D | U | A | SA | p-value |
|---|---|---|---|---|---|---|
| Scientific theories are subject to on-going testing and revision. | 0 | -13 | -6 | -6 | 25 | 0.1196 |
| Scientific theories may be completely replaced by new theories in light of new evidence. | 5 | -7 | -18 | 8 | 12 | 0.2624 |
| Scientific theories may be changed because scientists reinterpret existing observations. | 5 | -11 | -9 | -21 | 36 | 0.4291 |
| Scientific theories based on accurate experimentation will not be changed. | -11 | 32 | -33 | 3 | 9 | 0.3691 |

*Note.* SD = Strongly Disagree, D = Disagree, U = Uncertain, A = Agree, SA = Strongly Agree.

Scientific Laws vs. Theories

Mixed changes are found in student knowledge of scientific laws versus theories (Table 10). Again, T-Test values indicate none of the data sets are statistically significant. Many of the pretreatment responses (*N* = 15) were grouped in the *uncertain* column. Post treatment (*N* = 22), there were decreases in uncertainty in three out of the four questions asked in this category. However, the biggest gain for any category was for an incorrect response. Specifically, there was a 30% increase in students who agreed that *scientific laws are theories that have been proven* versus an 18% increase in those that disagreed. This is a misconception. Students appear to be more confident in understanding a scientific theory but are less confident in understanding scientific laws.

The MythBusters project appears to have very little impact on this specific NOS category.

Table 10
*Differences in Percentages and T-Test Analysis of Student NOS Understanding on Scientific Laws vs. Theories Pretreatment (N = 15) and Post Treatment (N = 22)*

| | SD | D | U | A | SA | p-value |
|---|---|---|---|---|---|---|
| Scientific theories exist in the natural world and are uncovered through scientific investigation. | -7 | 9 | -18 | 26 | -11 | 0.2815 |
| Unlike theories, scientific laws are not subject to change. | 2 | 7 | -13 | -8 | 12 | 0.1408 |
| Scientific laws are theories that have been proven. | 0 | 18 | -40 | 30 | -8 | 0.4215 |
| Scientific theories explain scientific laws. | 0 | -2 | 10 | -17 | 9 | 0.4473 |

*Note.* SD = Strongly Disagree, D = Disagree, U = Uncertain, A = Agree, SA = Strongly Agree.

Social and Cultural Influence

The data in this category are varied (Table 11). The first two statements have small differences in percentage increases among the post treatment students (*N* = 20) as compared to pretreatment (*N* = 15) that strongly agree and strongly disagree. The second two statements display increases in students that disagree and strongly disagree. Specifically, there was 15% increase in students that disagree and 10% in those that strongly disagree with the statement *cultural values and expectations determine how science is conducted and accepted.* Similarly, there was a 10% increase in the students who disagree and 13% in those that strongly disagree with the statement *all cultures conduct scientific research the same way because science is universal and independent of society and culture*. Students seem to recognize that science should be unbiased but that society does have a significant impact on it. Student comments reflect the data. One student stated, “Science is cold hard facts universally.” Another student said, “People are interested in different things due to their culture.” Finally, another student simply said, “Scientists are biased.” T-Tests performed on this data indicated the data was not significant.

Table 11
*Differences in Percentages and T-Test Analysis of Student NOS Understanding of Social and Cultural Influences Pretreatment (N = 15) and Post Treatment (N = 20)*

| | SD | D | U | A | SA | p-value |
|---|---|---|---|---|---|---|
| Scientific research is not influenced by society and culture because scientists are trained to conduct "pure", unbiased studies | 2 | -3 | 0 | -7 | 8 | 0.1490 |
| Cultural values and expectations determine <u>what</u> science is conducted and accepted. | 0 | 5 | -15 | 7 | 3 | 0.2391 |
| Cultural values and expectations determine <u>how</u> science is conducted and accepted. | 10 | 15 | -15 | -18 | 8 | 0.3456 |
| All cultures conduct scientific research the same way because science is universal and independent of society and culture. | 13 | 10 | -10 | -12 | -2 | 0.2387 |

*Note.* SD = Strongly Disagree, D = Disagree, U = Uncertain, A = Agree, SA = Strongly Agree.

<u>Imagination and Creativity</u>

Student responses tend to favor scientists using their imagination and creativity (Table 12). T-Tests indicate the data sets are not significant. There is a strong decrease amongst the post treated students (*N* = 20) away from uncertainty as compared to pretreatment responses (*N* = 15). There is a 23% increase among the students that agree with the statement *scientists use their imagination and creativity when they collect data*.

There is also a 15% increase in students who disagree and an 8% increase in those that strongly disagree when *scientists use their imagination and creativity when they analyze and interpret data.* The students that have been through scientific research can now see a difference between how they collect data and how they analyze it. The third statement has a nearly identical split in the differences in percentages. Furthermore, there is also a 12% increase in students who disagree with the statement *scientists do not use their imagination and creativity because these can interfere with objectivity*. Student comments reveal a difficulty in answering these statements as there appears to be a battle between those that think scientists cannot use imagination and just provide the facts versus those that see imagination as a vital part of science. One student said, “Scientists don’t use their imagination because it interferes with factual evidence.” Another student tried to justify when imagination can be used and when it can’t. “When thinking of theories they could use imagination and creativity, but when it comes to experiments they should not.” Another student stated, “Using imagination faults results.” Still another student took the opposite stance when he said, “It is hard to complete ideas without imagination.”

Table 12
*Differences in Percentages and T-Test Analysis of Student NOS Understanding of Use of Imagination and Creativity Pretreatment (N = 15) and Post Treatment (N = 20)*

| | SD | D | U | A | SA | p-value |
|---|---|---|---|---|---|---|
| Scientists use their imagination and creativity when they collect data. | 5 | -7 | -25 | 23 | 3 | 0.2123 |
| Scientists use their imagination and creativity when they analyze and interpret data. | 8 | 15 | -20 | 0 | 3 | 0.1460 |
| Scientists do not use their imagination and creativity because these conflict with their logical reasoning. | 8 | -12 | 2 | 10 | -8 | 0.2343 |
| Scientists do not use their imagination and creativity because these can interfere with objectivity. | 8 | 12 | -23 | 8 | -5 | 0.2037 |

*Note.* SD = Strongly Disagree, D = Disagree, U = Uncertain, A = Agree, SA = Strongly Agree.

Scientific Investigation

The data for scientific investigation is mixed in that there are no obvious differences in one statement and a conflict between two of the other statements (Table 13). For instance, there is an 11% increase in post treated students ($N$ = 19) that strongly agree that *scientists use a variety of methods to produce fruitful results* as compared to pretreatment responses ($N$ = 13). Yet, there is also a 22% increase in students that agree that *scientists follow the same step-by-step* method. One student said, “I think scientists should use both universal and different methods. Facts and results cannot be shown by only one way. It is important for scientists to see one thing from different perspectives.” Another student said, “There really isn’t a method to do science. There can be variety.” In addition, there were increases in the differences in percent values among treated students in those that strongly disagree, agree, and strongly agree with using the scientific method correctly to produce true and accurate results. This maybe another misconception because the scientific method doesn't produce true results so much as consistent results.

Table 13
*Differences in Percentages and T-Test Analysis of Student NOS Understanding of Scientific Investigations Pretreatment (N = 13) and Post Treatment (N = 19)*

| | SD | D | U | A | SA | p-value |
|---|---|---|---|---|---|---|
| Scientists use a variety of methods to produce fruitful results. | 0 | -10 | 5 | -6 | 11 | 0.4548 |
| Scientists follow the same step-by-step scientific method. | -2 | 6 | -20 | 22 | -5 | 0.2594 |
| When scientists use the scientific method correctly, their results are true and accurate. | 16 | -33 | -17 | 19 | 16 | 0.3520 |
| Experiments are not the only means used in the development of scientific knowledge. | 0 | 5 | 3 | -6 | -2 | 0.4399 |

*Note.* SD = Strongly Disagree, D = Disagree, U = Uncertain, A = Agree, SA = Strongly Agree.

In summary, students overall understanding of NOS did not significantly change as a result of conducting the MythBusters project. They have a good grasp on concepts related to observations and inferences, scientific theories, and use of imagination and creativity. Conversely, the students are muddied on concepts related to scientific laws versus theories, social and cultural influences, and scientific investigation. The data do lend themselves to an appreciation of the lab process. Perhaps a student said it best, "I gained an appreciation of science through the experiment and making a plan and all that. I figured out the real meaning of error. But my understanding didn't change."

# INTERPRETATION AND CONCLUSION

The results of this study were analyzed to answer my focus question on the effects the MythBusters project has on student understanding of lab processes, attitudes towards science, and understanding of NOS. Evaluation of the data has led me to conclude that the MythBusters project has had a very positive impact on student understanding of lab processes, skills, and attitude. The MythBusters project has given students involved in the treatment much greater self-confidence in various science skills regarding research. As a result of this increase in self-confidence, the MythBusters project has encouraged more students to consider going to school for science. With the application of the scientific method from an idea generated by individual groups, the T students gained a whole new perspective on *doing* science.

The application of doing science seemed to carry over into the daily science coursework as well. This can be seen in the attitude surveys where the initial attitudes for the MythBusters project were very high and started a slight downward trend by projects' end. During a small group interview, a number of students reported feeling like they understood more of what was happening in class now that they were more involved with their own scientific research. For clarification, I asked one of these students if that meant that he preferred being told about the science over doing the project. One student responded, "No! I'm just saying it's getting me more excited for class." In addition, a number of nontreated students in another chemistry class would make quick comments to me about how they would love to be doing the MythBusters project over their normal labs. This may explain why more nontreated students reported slightly higher attitudes towards doing science over the treated students in the attitude survey. Perhaps there is a desire to complete a similar project in which their peers are engaged.

Another positive development was the increased participation as the project went on. As the project progressed it became harder to work individually and the data reflects very positive group participation by the time the MythBusters project was completed. Many students learned the benefits, frustrations, and value of working with others towards a common goal. Communication and collaboration were particularly evident during the actual experiment phase of the MythBusters project. Student statements indicated they knew this would be a challenging and rewarding part of the project as working well with others is a life skill, not just a science skill.

The experience of doing scientific research, however, showed no significant improvements in student understanding of NOS. This is not surprising to me as it was not actively taught during the MythBusters project, but rather it was measured to see how well the students understood the implied knowledge while they were *doing* science. In that regard, the students tended to have stronger convictions regarding NOS questions they could relate to the project such as making observations and using imagination and creativity. They were more uncertain about the role science plays in society, and the differences between a scientific law and a theory.

Students gained a stronger interest in science and, ultimately, were better able to picture themselves pursuing science in higher education as a result of completing the MythBusters project. This realization, paired with a healthy attitude towards science, allowed students to become more interested in science class and strengthen their confidence to excel and more seriously consider the value of working with others.

## VALUE

I have been doing this project for five years now, and there are times during the project when I question why I put in so much work, but when the finished product is presented, I'm reminded why I feel this is so beneficial for my students. This action research has provided me with solid data that demonstrate the project's value to my students and also provided justification of its value for my colleagues and employers. I'm more aware of the positive impact a science project has on empowering students in their learning and the positive effects it has on their attitudes towards class and science in general. Many students have expressed wanting to try their MythBusters project again by testing new variables or would like to do a new MythBusters project again in the spring term.

If I were to do this research again, I would improve a couple of things. First, I would use information gained during this study to try to explain more clearly to my colleagues what I'm trying to accomplish. In doing so I may be able to gather more data from nontreated students in my colleague's chemistry classes. Information gained with nontreated students could provide more insight towards the MythBusters project's value on student understanding of science. Secondly, I would change my attitude survey instrument. I felt there were too many similar questions, a fact about which some of the students would express their annoyance to me. This may have also contributed to the slight downward trend in student attitude. I think I will also find some basic NOS articles or textbook readings to assign throughout the project and have some small class discussions to facilitate a better understanding of NOS and not just lab practices towards research. I could also provide periodic quizzes to assess what my students are learning from the process of completing the project.

In addition, I would like to make a teacher's assistant class composed of seniors who performed very well in my class and have been through the project once as sophomores. These senior assistants would each be assigned a couple of groups to provide more direct assistance. I typically have to keep track of the materials and safety of as many as sixteen different projects which means some groups don't get the best of my attention. MythBusters project TA's could make sure experiments and other aspects of the project are being completed in a timely manner, groups are following the rubric, and be a sounding board for groups to bounce ideas around. Another possibility is a course elective for upperclassmen that have more advanced science training comprised entirely of conducting MythBusters style experimental based projects. In this course, certain physical and chemical topics would be listed from which students would have to design a project. There might be two or three projects that would have to be completed per group for the course. This would give students who were not assigned to my class as sophomores a chance to do some fun research if they desired. Regardless of whether these ideas come to fruition or not, I will continue to do this project with my classes with refinements to better suit the learning of my students.

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APPENDICES

# APPENDIX A

## PILOT STUDY AND POST PROJECT INTERVIEW QUESTIONS

# MYTHBUSTERS PILOT STUDY AND POST PROJECT INTERVIEW QUESTIONS

1. Why did you choose your topic of interest?
2. What did this project teach you about the investigative process of science?
3. How did this project differ from our normal labs?
4. In comparing the project against our normal lecture centered class, what has helped you learn more about science and why?
5. Considering what you knew about the nature of science before the project, how has your understanding changed throughout the process?
6. What was the most beneficial part of the project? The hardest part?
7. Can you compare your learning in this project with past assignments? Was it more, less, the same?
8. What changes might you suggest to the project to make it better?
9. Is there anything else you want me to know?

# APPENDIX B

## SELF-CONFIDENCE SURVEY

SELF-CONFIDENCE SURVEY

This survey is to help both of us understand your level of confidence in conducting scientific research. As you learn or build up your science skills over this trimester you will be called upon to use your current and previous knowledge to carry out a project based on the Discovery channel show Mythbusters. Some of you may have conducted a science experiment before and others have not. Please indicate how confident you are in the following items below.

| I feel confident in… | | | *(circle one)* | |
|---|---|---|---|---|
| 1. Using our Friday/Saturday discussions, scientific journals, and websites to create a science research topic (a testable myth). | Very | Somewhat | Not Very | Not at all |
| 2. Designing the experimental procedures for carrying out the research on my myth. | Very | Somewhat | Not Very | Not at all |
| 3. Taking accurate measurements using various analytical lab equipment such as scales, graduated cylinders, and thermometers. | Very | Somewhat | Not Very | Not at all |
| 4. Using Excel or another graphing program to create graphs, tables, and figures. | Very | Somewhat | Not Very | Not at all |
| 5. Writing a scientific paper using experimental data to back up my statements. | Very | Somewhat | Not Very | Not at all |
| 6. That doing the Mythbusters project will increase my interest in science. | Very | Somewhat | Not Very | Not at all |
| 7. That doing scientific research will increase my desire to go to college to study science. | Very | Somewhat | Not Very | Not at all |

8. If you circled “not very” or “not at all” in response to any items above, please briefly explain below why you don’t feel confident.

# APPENDIX C

## MISCONCEPTION PROBE

MISCONCEPTION PROBE

# Misconception Probe: The Nature of Science

Image from http://marsrover.nasa.gov/gallery/press/spirit/20040318a/10-JG-04-hills-A074R1_br.jpg

There are many view points as to the nature of science (NOS). The National Science Teachers Association (NSTA) has the following position on the NOS: "Science is characterized by the systematic gathering of information through various forms of direct and indirect observations and the testing of this information by methods including, but not limited to, experimentation. The principal product of science is knowledge in the form of naturalistic concepts and the laws and theories related to those concepts (NSTA, 2011)." In another words, the information gathered through observation must be testable by scientific means. This position omits all non-scientific or pseudoscientific ideas, claims, and generalizations. The Myth Busters project is based on the ability to scientifically test myths and claims that are generated from history, folklore, and commonly held perceptions.

Check the myth below that is scientifically testable based on current human knowledge and technology and explain why?

________Eating poppy seed muffins will cause you to fail an illegal drug test.

________The fastest way to get from Albuquerque to Timbuktu is via teleportation.

________Upon death you are ferried along the river Styx to the underworld, Hades.

National Science Teachers Association (NSTA). *www.nsta.org.* (n.d.) Retrieved on 10-2-2011 from http://www.nsta.org/about/positions/natureofscience.aspx

# APPENDIX D

## MYTHBUSTERS PRE-PROJECT INTERVIEW QUESTIONS

# MYTHBUSTERS PRE-PROJECT INTERVIEW QUESTIONS

1. How do you feel the year in chemistry gone for you so far?
2. Describe what science means to you?
3. Thinking back on the self-confidence survey, what were you most confident in and why? What were you least confident in and why?
4. Thinking back on the misconception probe regarding the nature of science, what answer did you choose and why?
5. What do you know about the investigative process of science?
6. How do you expect this project to be different from other labs we have conducted?
7. What are you hoping to learn from this project?
8. What do you anticipate will be the hardest part and why?
9. Is there anything else you want me know?
10. What changes might you suggest to the project to make it better?
11. Is there anything else you want me to know?

# APPENDIX E

## THE MYTH GRADING RUBRIC

THE MYTH GRADING RUBRIC

## MythBusters Project Grade Sheet

**Group:**____________________________________________________

Part One: Selection of the Myth 0 1 2 3 4 5

- The myth is testable by experimentation _____
- Selection process of your myth _____
- Description of the experiment _____
- Spelling and Grammar _____
- Total _____

| Category | 5 | 4 | 3 | 2 | 1 | 0 |
|---|---|---|---|---|---|---|
| The myth is testable by experimentation | The myth is typed in one to three sentences, is a scientifically testable statement, and is clearly defined as to how it is related to chemistry in some way. | One or two minor details missing. | Relationship to chemistry is unclear or not well defined. | Not related to chemistry. | Myth is not testable. | No attempt made. |
| Selection process of your myth | A paragraph is written that clearly states how and why the myth was chosen for the group. Where the myth was found is identified and cited in text using APA formatting. The group identifies why this myth is interesting to them. | One or two minor details missing. | How the myth was chosen is unclear or not well defined or improper APA citation. | Part of the selection process is missing &/or APA citation is missing. | Information had little to do with the main topic guidelines. | No attempt made. |
| Description of the experiment | A brief paragraph is written about what the group intends to test and | The experiment was solid but one or two minor details were | Missing one of the variables &/or expected result. Needs | Many details are lacking including both variables | No details are given. The experimental description is | No attempt made. |

| | | | | | | |
|---|---|---|---|---|---|---|
| | how. The independent and dependent variables are clearly identified as well as the expected result. | overlooked. | more details. | & the expected result. | seriously flawed. | |
| Spelling and Grammar | No major spelling mistakes or grammar problems. The paper is in the proper paragraph formatting (Times New Roman 12 point font, and double-spaced). | Minor spelling mistakes. | Minor grammar mistakes | One major grammar &/or formating mistake | Two or more major spelling and grammar mistakes | Illegible |

# APPENDIX F

## TEACHER JOURNAL PROMPTS*

*Adapted from Rolke, 2011.

# TEACHER JOURNAL PROMPTS

Project Phase: Date:

General reflections on the project phase: 1 2 3 4 5

Student attitude towards science project: 1 2 3 4 5
Observations/comments:

Student desire to learn: 1 2 3 4 5
Observations/comments:

Students were engaged in the project 1 2 3 4 5
Comments:

Students having problems working in group: 1 2 3 4 5
Observations/comments:

My attitude toward activity and students: 1 2 3 4 5
Comments:

# APPENDIX G

STUDENT ATTITUDE SURVEY

STUDENT ATTITUDE SURVEY

Dear student,

This test contains a number of statements about science. You will be asked what you yourself think about these statements. There are no right or wrong answers. Your opinion is what is wanted. Please circle your response to the items. Rate aspects of the course on a 1 to 7 scale, 1 equals "strongly disagree" and 7 equals "strongly agree". 1 represents the lowest and most negative impression on the scale, 4 represents an adequate impression, and 7 represents the highest and most positive impression.

| | strongly disagree | | | not sure | | | strongly agree |
|---|---|---|---|---|---|---|---|
| I would prefer to find out why something happens by doing an experiment than by being told. | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| Science lessons are fun. | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| Doing experiments is not as good as finding out information from teachers. | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| I dislike science lessons. | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| I would prefer to do experiments than to read about them. | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| School should have more science lessons each week. | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| I would rather agree with other people than do an experiment to find out for myself. | 1 | 2 | 3 | 4 | 5 | 6 | 7 |

***Turn over for more questions.***

| | strongly disagree | | | not sure | | | strongly agree |
|---|---|---|---|---|---|---|---|
| Science lessons bore me. | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| I would prefer to do my own experiments than to find out information from a teacher. | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| Science is one of the most interesting school subjects. | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| I would rather find out about things by asking an expert than by doing an experiment. | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| Science lessons are a waste of time. | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| I would rather solve a problem by doing an experiment than be told the answer. | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| I really enjoy going to science lessons. | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| It is better to ask the teacher the answer than to find it out by doing experiments. | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| The material covered in science lessons is uninteresting. | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| I would prefer to do an experiment on a topic than to read about it in science magazines. | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| I look forward to science lessons. | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| It is better to be told scientific facts than to find them out from experiments. | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| I would enjoy school more if there were no science lessons. | 1 | 2 | 3 | 4 | 5 | 6 | 7 |

**Adapted from**: *Test of Science-Related Attitudes (TOSRA): Fraser, B. L. (1978). Development of a test of science-related attitudes. Science Education, 62, 509-515. (Public Domain)*

*Science Questionnaire. www.coldex.info. (n.d.) Retrieved on October 22, 2011 from* www.coldex.info/contact/OUS_**Questionnaires**.pdf

# APPENDIX H

## NATURE OF SCIENCE (NOS) QUESTIONNAIRE*

NOS QUESTIONNAIRE

## Student Understanding of Science and Scientific Inquiry Questionnaire

**Please read EACH statement carefully, and then indicate the degree to which you agree or disagree with EACH statement by circling the appropriate letters to the right of each statement.**

**SD= Strongly Disagree**
**D = Disagree More Than Agree**
**U = Uncertain or Not Sure**
**A = Agree More Than Disagree**
**SA = Strongly Agree**

| **1. Observations and Inferences** | | | | | |
|---|---|---|---|---|---|
| A. Scientists' observations of the same event may be different because the scientists' prior knowledge may affect their observations. | SD | D | U | A | SA |
| B. Scientists' observations of the same event will be the same because scientists are objective. | SD | D | U | A | SA |
| C. Scientists' observations of the same event will be the same because observations are facts. | SD | D | U | A | SA |
| D. Scientists may make different interpretations based on the same observations. | SD | D | U | A | SA |

Explain why you think scientists' observations and interpretations are the same or different?

| **2. Nature of Scientific Theories** | | | | | |
|---|---|---|---|---|---|
| A. Scientific theories are subject to on-going testing and revision. | SD | D | U | A | SA |
| B. Scientific theories may be completely replaced by new theories in light of new evidence. | SD | D | U | A | SA |
| C. Scientific theories may be changed because scientists reinterpret existing observations. | SD | D | U | A | SA |
| D. Scientific theories based on accurate experimentation will not be changed. | SD | D | U | A | SA |

Explain why you think scientific theories change or do not change over time.

| 3. **Scientific Laws vs. Theories** | | | | | |
|---|---|---|---|---|---|
| A. Scientific theories exist in the natural world and are uncovered through scientific investigations. | SD | D | U | A | SA |
| B. Unlike theories, scientific laws are not subject to change. | SD | D | U | A | SA |
| C. Scientific laws are theories that have been proven. | SD | D | U | A | SA |
| D. Scientific theories explain scientific laws. | SD | D | U | A | SA |

Explain the difference between scientific theories and scientific laws.

| 4. **Social and Cultural Influence on Science** | | | | | |
|---|---|---|---|---|---|
| A. Scientific research is not influenced by society and culture because scientists are trained to conduct "pure", unbiased studies. | SD | D | U | A | SA |
| B. Cultural values and expectations determine what science is conducted and accepted. | SD | D | U | A | SA |
| C. Cultural values and expectations determine how science is conducted and accepted. | SD | D | U | A | SA |
| D. All cultures conduct scientific research the same way because science is universal and independent of society and culture. | SD | D | U | A | SA |

Explain how society and culture affect or do not affect scientific research.

| 5. Imagination and Creativity in Scientific Investigations | | | | | |
|---|---|---|---|---|---|
| A. Scientists use their imagination and creativity when they collect data. | SD | D | U | A | SA |
| B. Scientists use their imagination and creativity when they analyze and interpret data. | SD | D | U | A | SA |
| C. Scientists do **not** use their imagination and creativity because these conflict with their logical reasoning. | SD | D | U | A | SA |
| D. Scientists do **not** use their imagination and creativity because these can interfere with objectivity. | SD | D | U | A | SA |

Explain why scientists use or do not use imagination and creativity?

| 6. Scientific Investigation | | | | | |
|---|---|---|---|---|---|
| A. Scientists use a variety of methods to produce fruitful results. | SD | D | U | A | SA |
| B. Scientists follow the same step-by-step scientific method. | SD | D | U | A | SA |
| C. When scientists use the scientific method correctly, their results are true and accurate. | SD | D | U | A | SA |
| D. Experiments are not the only means used in the development of scientific knowledge. | SD | D | U | A | SA |

Explain whether scientists follow a single, universal scientific method or use different methods.

*Student Understanding of Science Questionnaire. www.arapha.nsuok.edu. (2005, August 18). Retrieved on October 22, 2011 from arapaho.nsuok.edu/~nsutpc/Instruments/SUSSI_Aug_18_05.pdf*

# APPENDIX I

STUDENT PARTICIPATION SURVEY*

# Student Participation Survey

| | 4<br>Always | 3<br>Almost Always | 2<br>Sometimes | 1<br>Never |
|---|---|---|---|---|
| Did I do my jobs and was I prepared to meet and work with my group? | | | | |
| Did I share information with my team that related to our assignment? | | | | |
| Did I listen to everyone in the group and give everyone a chance to speak? | | | | |
| Did I cooperate with my group and not argue with them? | | | | |

Other comments or concerns:

**Utah State Office of Education/Utah State University*

# APPENDIX J

## MYTHBUSTERS PLAN RUBRIC

MYTHBUSTERS PLAN RUBRIC

**MythBusters Project Grade Sheet**

**Group:____________________________________________________**

Part Two: Preparing the Plan 0 1 2 3 4 5

Background of Myth

- Literature review of the myth's origination _____
- Scientific explanation of the expected result _____
- Bibliography _____

Procedure for Investigation

- Variables and controls identified _____
- Complete materials list _____
- Numbered and detailed procedure _____
- Safety procedures _____

Plan to Record and Organize Observations/Data

- Space for measured/calculated area _____
- Data Tables _____
- Organized sequentially _____
- Labeled fully (units included) _____

- Spelling and Grammar _____

Total _____

| Category | 5 | 4 | 3 | 2 | 1 | 0 |
|---|---|---|---|---|---|---|
| Literature review of the myth's origination | A complete background and research is provided about the origins of the myth. A thorough and descriptive review of the literature is presented. | The literature review was related to the myth but one or two pieces of info were missing from the review. | The literature review is related to the myth but a critical piece of info is missing from the review. | The information presented is loosely related to the myth but a thorough review was not presented. | Information had little or nothing to do with the main topic. | No attempt made. |
| Scientific explanation of the expected result | A thorough explanation of the intended science is presented in regards to the expected result. The relationship to chemistry is clear. | The science presented is mostly accurate but one or two things are missing. The chemistry is mostly clear. | The science is unclear and the chemistry is vague. More details are needed. | The science is critically flawed. | Explanation given had little to do with a scientific explanation of the myth. | No attempt made. |
| Bibliography | All sources are referenced using APA format. The science is from scientific sources. | Sources are good but one or two issues with formatting. | Not all science sources are valid. A few issues with formatting. | Major issues with APA formatting or most of the sources are nonscientific. | No valid science sources or complete lack of formatting. | No attempt made. |
| Variables and controls identified | Both variables and all controls | Both variables are identified | One of the variables is missing but all | One of the variables is missing and no | Both variables are missing | No attempt made. |

| | | | | | | |
|---|---|---|---|---|---|---|
| | are clearly identified. | but one control is missing. | controls are identified. | controls are identified. | but one control is identified. | |
| Complete materials list | All materials as well as quantities needed are clearly identified. | All materials are identified but some of the quantities are missing. | Some materials are not mentioned and some of the quantities are missing. | Some of the materials are mentioned but no quantities are given. | Very little attempt was made to make a materials list with proper quantities. | No attempt made. |
| Numbered and detailed procedure | Very detailed plan is presented. Another group could follow this without any problems. | A pretty thorough plan but it is missing one or two steps or missing some specific quantities. | The procedure is unclear in spots and missing specifics. Another group would fumble their way through this lab. | The plan is lacking a number of details and specifics. Others would find it very difficult to follow this plan with any achievable result. | A complete lack of detail and effort. No other person could figure out what to do in this project. | No attempt made. |
| Safety procedures | All hazards are identified and a detailed procedure is creating showing how to avoid and protect the group members from these hazards. | All hazards are identified, but one or two safety precaution s are missing from the safety procedure. | At least one major safety hazard was missed and/or the safety procedure is not adequate to address a major hazard. | Many oversights on safety or safety procedure is very inadequate. | Very little effort put into identifying hazards to personal safety and the procedure is completel y inadequate . | No attempt made. |
| Space for measured/calcul ated area | Space is allowed for manipulati on or calculation of measured | Space is allowed for calculatio ns and observatio ns but one of the | Two or more calculatio n are not identified or the space for observatio | Very little space given and calculation s are not identified. | It's unclear what is intended to go into the space. | No attempt made. |

| | | | | | | |
|---|---|---|---|---|---|---|
| | data or qualitative observation. All expected calculations are identified in the data collecting area. | calculations are not clearly identified. | ns is inadequate. | | | |
| Data Tables | A thorough data table is given complete with all columns and rows are identified and correct units of measure are used. The data table has a title. | A thorough data table is given complete with proper units, but a title is missing. | Title is missing, and/or some of the rows and columns are not properly labeled with units. | Title is missing and/or most of the rows and columns are missing units. | A table is provided but it is completely unlabeled. | No attempt made. |
| Organized sequentially | All of the plan components follow a logical progression of a science paper. The plan is organized so that recording follows as data is generated. | The paper follows good organization with the exception of one or two sections out of proper order. | Two to three sections are out of a sequence. | Many sections are out of order. The reader has a difficult time moving from one section to the next. | Very little organization. Appears almost random. | No attempt made. Completely random organization. |
| Labeled fully (units included) | All data collection tables and anticipated calculations display | Very good use of correct units but one is mislabele | Some units are missing or incorrect. | Many incorrect units are displayed. | Many missing units from data collection tables and | No attempt made. |

| | | | | | | |
|---|---|---|---|---|---|---|
| | correct units of measure. | d. | | | anticipated calculation s. | |
| Spelling and Grammar | No major spelling mistakes or grammar problems. The paper is in the proper paragraph formatting (Times New Roman 12 point font, and double-spaced). | Minor spelling mistakes. | Minor grammar mistakes | One major grammar &/or formatting mistake | Two or more major spelling and grammar mistakes | Illegible |

# APPENDIX K

## MYTHBUSTERS EXPERIMENT RUBRIC

MYTHBUSTERS EXPERIMENT RUBRIC

**MythBusters Project Grade Sheet**

**Group:**______________________________________________________

Part Three: Conducting the Experiment 0 1 2 3 4 5

Experimental Conduct
- Completion of all planned trials _______
- Lab clean up _______

Quality of Observations/Data
- Accurate measurements/observations _______
- Completed data table _______

Graphs
- Appropriate graph chosen for data trend _______
- Data plotted accurately _______
- Axes labeled with correct variables _______

Calculations
- Calculated accurately _______
- Units used correctly _______

Data Analysis
- Summary of the data _______
- References to calculations and graphs _______

Forms a Conclusion from the Experiment
- States myth is plausible, busted, or confirmed _______
- Sources of error and revised procedure _______

- Spelling and Grammar _______

Total _______

| Category | 5 | 4 | 3 | 2 | 1 | 0 |
|---|---|---|---|---|---|---|
| Completion of all planned trials | Three or more trials of data were completed in a timely manner. | Three sets of data were collected but the last is not as consistent as the first two due to time constraints. | The third data set was only partially completed. | Only two sets of data were collected. | Only one set of data was collected. | Not applicable. If this situation occurs then the groups has earned a 0 for the remainder of the project. |
| Lab clean up | All work spaces are cleaned up and materials have found their way back to their proper places. All chemicals are properly stored and put away. | One or two objects were left out or a small mess was left for someone else to clean. All chemicals were properly stored and put away. | A bunch of small messes are left for others to clean and materials are not all put away. | A major mess was left for others to clean and materials have been left out. | A major mess was left for others to clean and materials as well as chemicals have been left out. | Major messes were left for others to clean and dangerous chemicals are left out where others could get seriously hurt. |
| Accurate measurements & observations | Detailed qualitative observations are made along with appropriate quantitative measurements for the experiment. | Observations are missing one or two details but the quantitative data is appropriate for the trials. | There are a few holes in the qualitative observation and some of the quantitative data is flawed or missing. | No attempt made at obtaining observations and some of the quantitative data is flawed or missing. | No observation and many flaws in quantitative measurements | No observations or measurements. |
| Completed data table | Data table has a descriptive title, all columns are labeled and appropriate units are displayed with each measurement or calculation. | A descriptive title is missing or one of the columns is not labeled or some of the measurements are missing units. | A title is missing plus multiple columns are unlabeled or there is a title but no column labels and some units are missing. | Missing title and column labels. Units may or may not be well used. | No title, no column labels, and no units. It’s just a table of unknown numbers. | No attempt made. |

| | | | | | | |
|---|---|---|---|---|---|---|
| Appropriate graph chosen for data trend | Data plot chosen is a good fit and representation of the data. | N/A | The plotted data can be displayed in the chosen graph but a better option could have been utilized. | N/A | Chosen graph is a poor representation of the data. | No graph or chart was made. |
| Data plotted accurately | Plotted points are equal to data values & value of the scale is appropriate to range of data with suitable increments. | N/A | Plotted points are equal to data values but the value of scale is inappropriate to the range of data. | N/A | Plotted points are not equal to the data values and the scale is inappropriate to the range of data. | No data was plotted on a graph or chart. |
| Axes labeled with correct variables and chart title. | The graph has a descriptive title along with each axes labeled with correct variables and units. | The graph title is not descriptive or missing but the graph has axes labeled with correct variables and units. | The graph title is missing and one of the axes labels is missing correct units or both axes contain the wrong variable. | The graph title is missing and one of the axes labels is missing or mislabeled. | The graph title is missing and both axes are mislabeled and contain incorrect units. | No title or axes labels. It is a completely unlabeled graph. |
| Calculated accurately | Calculations are complete and mathematically correct. Results are expressed to correct sig figs. | Calculations are complete and mathematically correct. Results are expressed with wrong sig figs. | Calculations are complete but one is not mathematically correct. | Calculations are complete but two or three are not mathematically correct. | All calculation are complete but incorrect. | No calculation have been made that should have been made. |
| Units used correctly | All calculated values are expressed with appropriate units. | One calculated value is using an inappropriate unit. | Two to three of the calculations contain inappropriate units. | Calculations have a combination of incorrect units and / or missing | Most calculated values are missing units. | All calculations are missing units. |

| | | | | | | |
|---|---|---|---|---|---|---|
| | | | | some units | | |
| Summary of the data | The data is thoroughly analyzed and well organized. Themes are identified. | Most of the data is well analyzed. | The data is somewhat analyzed but not well organized. Some themes are identified. | The data is somewhat analyzed but not well organized. No themes are identified. | The data is poorly analyzed and not organized. No themes are identified. | No real attempt was made to summarize the data. |
| References to calculations and graphs | All tables, figures, and charts are appropriately referred to during the summation of data. | N/A | One or more of the figures, tables, and charts are not specifically referenced during the summary of data. | N/A | No specific reference to data. Only vague inferences. | No attempt to reference data made. |
| States myth is plausible, busted, or confirmed | A conclusion is made and backed by an explanation of the data that is consistent with experimental results. | A conclusion is made and is consistent with experimental results but at least one thing is not well explained using data. | A conclusion is made and is consistent with experimental results but it is not well explained using data. | A conclusion is made that is not entirely consistent with the data. The explanation needs a lot of work. | A conclusion is made that is not consistent at all with the data. The explanation needs a lot of work. | No conclusion is made. |
| Sources of error and revised procedure | Probable sources of error are identified and explained. Any revisions to the approved procedure are identified and explained. | Sources of error and / or revisions to procedures are decent but could use more explanation. | Sources of error are not well explained. Revised procedures are decently explained. | Both sources of error and revisions to procedures are not well explained. | Sources of error are vague or missing and revised procedures are poorly done and not well explained. | No attempt made. |
| Spelling and | No major spelling | Minor spelling | Minor grammar | One major grammar | Two or more | Illegible |

| | | | | | | |
|---|---|---|---|---|---|---|
| Grammar | mistakes or grammar problems. The paper is in the proper paragraph formatting (Times New Roman 12 point font, and double-spaced). | mistakes. | mistakes | &/or formatting mistake | major spelling and grammar mistakes | |

# APPENDIX L

## MYTHBUSTERS POSTER RUBRIC

MYTHBUSTERS POSTER RUBRIC

# MythBusters Project Grade Sheet

**Group:**______________________________________________________

| Part Four: Creating the Poster | 0 1 2 3 4 5 |
|---|---|
| • Scientific title & stated myth | ______ |
| • Abstract | ______ |
| • Illustrated procedure | ______ |
| • Materials & safety | ______ |
| • Data tables/charts with captions | ______ |
| • Graphs with captions | ______ |
| • Myth conclusions/discussion | ______ |
| • Calculations | ______ |
| • How would you improve your project | ______ |
| • Organization and creativity | ______ |
| • Resources | ______ |
| • Spelling and Grammar | ______ |
| • Total | ______ |

| Category | 5 | 4 | 3 | 2 | 1 | 0 |
|---|---|---|---|---|---|---|
| Scientific title & stated myth | A scientific title is clearly displayed and the myth is typed in one sentence, and is a scientifically testable statement. | A good effort but details are missing on either the title or the myth. One of them is not easily identifiable. | Both title and myth are not very detailed and are not easily located on the poster. | Title or myth is missing. | Title or myth is missing and the other is not very detailed. | Both title and myth are missing. |
| Abstract | A detailed summary of the myth project is given complete with variables, controls, a brief procedure, findings, and conclusions. The entire abstract should be concise 10-12 sentences. | One or two pieces of info is missing or the abstract is slightly too short or too long. | Multiple pieces of info missing and the abstract is slightly too short or too long. | Abstract is poorly written and is too short or too long. | Five or more pieces of info missing. Abstract is poorly written and is too short or too long. | No attempt made. |
| Illustrated procedure | A summary of the procedure is presented along with pictures or illustrations to visualize the process. The most critical steps are identified by the procedure. | A pretty good attempt at an illustrated procedure but it is missing one or two steps critical steps to the process. | The procedure is either too general or is not well organized or is missing an illustration or two. | The procedure is lacking a number of critical details and it only has one or two illustrations. | A complete lack of detail and effort. No illustrations are provided. | No attempt made. |
| Materials | All | All | Some | Some of the | Very | No |

| | | | | | | |
|---|---|---|---|---|---|---|
| & safety | materials as well as quantities needed are clearly identified. All hazards are identified and a detailed procedure is creating showing how to avoid and protect the group members from these hazards. | materials are identified but some of the quantities are missing. All hazards are identified, but one or two safety precautions are missing from the safety procedure. | materials are not mentioned and some of the quantities are missing. At least one major safety hazard was missed and/or the safety procedure is not adequate to address a major hazard. | materials are mentioned but no quantities are given. Many oversights on safety or safety procedure is very inadequate. Very little effort put into identifying hazards to personal safety and the procedure is completely inadequate. | little attempt was made to make a materials list with proper quantities. | attempt made. |
| Data tables/charts with captions | Data table has a descriptive title, all columns are labeled and appropriate units are displayed with each measurement or calculation with a caption underneath the table. | A descriptive title is missing or one of the columns is not labeled or some of the measurements are missing units. No caption present. | A title is missing plus multiple columns are unlabeled or there is a title but no column labels and some units are missing. No caption present | Missing title and column labels. Units may or may not be well used. No caption present | No title, no column labels, and no units. It's just a table of unknown numbers. No caption present | No attempt made. |
| Graphs with captions | The graph has a descriptive title along with each axes labeled with correct variables and units and a | The graph title is not descriptive or missing but the graph has axes labeled with correct variables and units. | The graph title is missing and one of the axes labels is missing correct units or both axes contain the | The graph title is missing and one of the axes labels is missing or mislabeled. No caption present. | The graph title is missing and both axes are mislabeled and contain incorrect | No title or axes labels. It is a completely unlabeled graph without a caption. |

| | | | | | | |
|---|---|---|---|---|---|---|
| | caption underneath the graph. | There is no caption | wrong variable and there is no caption. | | units. No caption present. | |
| Myth conclusions / discussions | A conclusion paragraph is made and backed by an explanation of the data that is consistent with experimental results. Myth is stated as plausible, confirmed, or busted. | A conclusion is made and is consistent with experimental results but at least one thing is not well explained using data. | A conclusion is made and is consistent with experimental results but it is not well explained using data. | A conclusion is made that is not entirely consistent with the data. The explanation needs a lot of work. | A conclusion is made that is not consistent at all with the data. The explanation needs a lot of work. | No conclusion is made. |
| Calculations | Calculations are complete and mathematically correct. Results are expressed to correct sig figs. All calculated values are expressed with appropriate units. | Calculations are complete and mathematically correct. Results are expressed with wrong sig figs. One calculated value is using an inappropriate unit. | Calculations are complete but one is not mathematically correct. Two to three of the calculations contain inappropriate units. | Calculations are complete but two or three are not mathematically correct. Calculations have a combination of incorrect units and / or missing some units. | All calculation are complete but incorrect. Most calculated values are missing units. | No calculation have been made that should have been made. All calculations are missing units. |
| How would you improve your project | The group identifies how to improve the project based on methodology, sources of error, or an extension of the project to | A good job but the improvement is missing a detail or two from the methodology or the sources of error. | The extension of the project is fairly weak, or the improvement does not do enough to reduce sources of error. | A fairly week extension and error in the experiment was not considered. | The proposal has nothing to do with improving the experiment. | No attempt made. |

| | | | | | | |
|---|---|---|---|---|---|---|
| | investigate new things. | | | | | |
| Organization and creativity | The project info is well organized on the poster and the poster is visually appealing and enhances the scientific info without overwhelming it. | N/A | The project info is not that well organized or the poster is not very aesthetically pleasing. | N/A | The project info is not well organized and it is not aesthetically pleasing to the eye. | N/A |
| Resources | All sources are referenced using APA format. The science is from scientific sources. | Sources are good but one or two issues with formatting. | Not all science sources are valid. A few issues with formatting. | Major issues with APA formatting or most of the sources are nonscientific. | No valid science sources or complete lack of formatting. | No attempt made. |
| Spelling and Grammar | No major spelling mistakes or grammar problems. The paper is in the proper paragraph formatting (Times New Roman 12 point font, and double-spaced). | Minor spelling mistakes. | Minor grammar mistakes | One major grammar &/or formatting mistake | Two or more major spelling and grammar mistakes | Illegible |

# APPENDIX M

## MYTHBUSTERS PRESENTATION RUBRIC

MYTHBUSTERS PRESENTATION RUBRIC

# MythBusters Project Grade Sheet

**Group:**______________________________________________________

Part Five: Project Presentation 0 1 2 3 4 5

- Presentation of 5 to 10 minutes in length ______
- All groups members are involved ______
- Proper speech etiquette ______
- Use of visual aides ______
- Scientific content ______
- Creativity of presentation ______
- Total ______

| Category | 5 | 4 | 3 | 2 | 1 | 0 |
|---|---|---|---|---|---|---|
| Presentation of 5 to 10 minutes in length | Presentation is well rehearsed and the talk flows very naturally. Length is between 5 & 10 minutes. | Frequently pauses, or “um or uh” heard in the presentation. Length is between 5 & 10 minutes. | Presenters are between 4-5 mins or 10-11 mins on their talk. | Presenters are between 3-4 mins or over 12 mins on their talk. | Talk is under 3 minutes or over 13. | N/A |
| All groups members are involved | All groups members have equal parts and responsibilities in the talk. | One group member says very little and the other(s) dominate the talk. | One group member says nothing while the other(s) dominant or there is one dominate speaker and the other members say little. | One group member says nothing, the other very little, and one dominates the talk. | All members are reluctant to say much during the talk. | N/A |
| Proper speech etiquette | Speech is well rehearsed. The members speak to the class not off the projector or project board. There is little “um’s or uh’s” and the talk transitions easily between group members. | Speech is mostly smooth. There is some “um’s or uh’s” but no reading off the poster or projector. Transitions are okay between group members. | Speech is a little rough. Transitions are not very smooth between members. There is a lot of “um’s or uh’s” but very little reading off the poster or projector. | Speech is very rough and not well rehearsed. Transitions are not planned and are rough. Frequent pauses, “um’s or uh’s”. Group members have to read off poster or projector to keep talk moving. | Speech is not planned and is completely improvised. There is no organization to it. | |
| Use of visual | Group effectively | N/A | Group attempts to | N/A | Group only uses | N/A |

| | | | | | | |
|---|---|---|---|---|---|---|
| aides | uses technology, Power Point, Prezi, poster display, or small scale demonstration to enhance their talk. | | use with some but limited success technology, Power Point, Prezi, poster display, or small scale demonstration to enhance their talk. | | science poster and has no other visuals to enhance their talk. | |
| Scientific content | Group effectively takes us through the journey of selecting the myth, the background research, creating the plan, data found during the experiment and conclusions they drew from that data regarding the validity of their myth. | Group takes us through the journey but should have spent more time explaining the data and graphs that led to the group's conclusion. | Group doesn't spend enough time on the background research or the data found in order to properly back up their conclusions. | Group glosses over the entire journey without much detail and does not spend much time on how they made their conclusions about their myth. | Group does not spend any time on the science process and instead tries to distract and wow the audience with a bunch of visual aids. | N/A |
| Creativity of presentation | All group members are enthusiastic about their talk and the talk is fun and interesting. Group put a lot of planning into their talk. | N/A | Presentation was pretty average. Group was going through the motions but not overly enthusiastic about their talk. | N/A | A clear case of one group member trying very hard to put forth a creative presentation without any support | No attempt made at being creative. |

| | | | | | | |
|---|---|---|---|---|---|---|
| | | | | | from fellow group members. | |

# APPENDIX N

STUDENT GRADE COMPARISON

STUDENT GRADE COMPARISON

| Student ID # | Fall Exam Grade | Winter Exam Grade | MythBusters Grade | Significant Difference |
|---|---|---|---|---|
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