# PROVE IT! TESTING A TEACHING STRATEGY TO DEVELOP ARGUMENTATION SKILLS

by

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A professional paper submitted in partial fulfillment
of the requirements for the degree

of

Master of Science

in

Science Education

MONTANA STATE UNIVERSITY
Bozeman, Montana

July 2012

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July 2012

# DEDICATION

This paper is dedicated to my best friend of 30 years, my wife Jayne. Without her encouragement, support, patience, and understanding, my life would not have the future, the sunshine and the love it has now. I also dedicate this to my children; the real teachers, who taught me much more about life, the meaning of family and love than they will ever know.

ACKNOWLEDGEMENTS

I would like to thank Dr. Eric Brunsell for his direction, suggestions and assistance during this journey. I extend my thanks to my committee members Dr. John Amend, and Dr. Anita Welch. I also am indebted to Laurie Rugemer for her assistance during the writing and preparation of this paper. The entire faculty and staff of the MSSE program also deserve thanks for their concern and aid during my studies.

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# ABSTRACT

Students at Norman County East High School learn science concepts in a typical teacher-centered approach. In moving toward an inquiry-based, student-centered learning environment, it is imperative that students develop skills of critical thinking and argumentation. To accomplish this, students must be able to define a problem, select strategies for solving the problem and defend their choices. This study will attempt to evaluate the amount of improvement of their argumentation skills through the use of a game using the principles of argumentation as stated by Toulmin. Three questions will guide this study:

1. Will activities emphasizing argumentation lead to more sophisticated explanations of curriculum concepts by students?
2. Will students effectively critique each other?
3. Will argumentation assist students in explaining relationships between scientific concepts and what has been observed?

The study will take place in a class of grade 9 Physical Science students consisting of 12 girls and 5 boys. Data will be collected using pre and post testing of the concepts of density, buoyancy, heat and thermodynamics. Interviews and formative assessments of students before and after they participate in the studies activities and artifacts from the activity will be coded to measure changes in argumentation performance.

# INTRODUCTION AND BACKGROUND

## Project Background

### Teaching and Classroom Environment

For the past nine years I have been teaching Earth Science (eighth grade), Physical Science (ninth grade), Chemistry and Physics on a full-time basis at Norman County East ISD # 2215 in Twin Valley, Minnesota. The total enrollment in our school which serves grades 7-12 is 180. The school district is classified as a rural, low income school in an agricultural area of the Red River Valley in northwest Minnesota**.** The students of Norman County East come mainly from the many farms in the county with more than fifty percent of the students receiving free and reduced cost meals. The largest town of a population over 5,000 is Fargo, North Dakota which is 60 miles away. Many students are related to each other and nearly all have been in classes with their peers for several years. While there is some turnover of students, most students have been in the same cohort since elementary school. Typical population sizes of each grade range between 20 and 30 students. The predominate ethnic group is Caucasian with less than five African-American students and less than ten students of Native American heritage enrolled at the high school. The core curriculum staff includes one social studies teacher, one English teacher, two math teachers, two science teachers, one art teacher, one family and consumer science teacher, two special education teachers and several paraprofessionals along with office, janitorial and kitchen staff. The school is supported by an involved community even though it has seen substantial financial challenges the past few years.

Research Question

Inquiry learning has been found to be the most effective type of learning for retention of knowledge of many scientific concepts. National and state standards emphasize that students should develop knowledge based on the principles of constructivist learning embodied in the processes of inquiry as defined by the National Research Council. However, curricular material is often presented as 'teacher-centered' instead of 'student-centered'. In a 'student-centered' approach, students typically follow a constructivist learning philosophy that is commonly termed 'inquiry'. The current movement in science education relies heavily upon the constructivist approach to learning called inquiry. The basic underlying assumption is that students construct their own knowledge of a concept by engaging in activities that require the synthesis of data, critical thinking and the communication of their understandings. In recent years, the communication of that learning has been termed argumentation and has become more and more emphasized even though there has been relatively little formal study of the methods of teaching argumentation (Simon, 2008). Referring to a study by M. Billing in 1987, Simon (2008) further states that: "Arguments about the interpretation of evidence and the validity of knowledge claims are central to science and scientific discourse. From a cognitive perspective, argument is an important feature of reasoning and thinking" (p. 287). As described by Sampson and Clark (2008), several researchers have established protocols for classifying the elements of argumentation and more and more researchers are studying the effectiveness of teaching argumentation. They conclude their study with an important statement:

> While research to date has provided substantial and valuable empirical foundations for science education to build upon, more research examining the underlying causes of these patterns and themes will prove valuable in developing new curricular materials, instructional approaches, and technology-enhanced learning environments to promote and support more productive argumentation inside the classroom. (p. 470)

This study aims to develop a protocol to teach the basic elements of argumentation to grade nine students using direct instruction. In addition, this study seeks to test the effectiveness of a newly developed activity during which students will critique each other's arguments. The activities will consist of open-ended scenarios in which the student will apply their knowledge of curricular concepts to argue and explain their reasoning about the given question. In doing so they use the elements of argumentation to support their ideas and critique their classmate. The questions I will investigate will therefore be:

1. Can the basics of argumentation be taught through direct instruction and the use of a peer-critiquing activity?
2. Will activities emphasizing argumentation lead to more sophisticated explanations by students of the concepts of sinking and floating, buoyancy, heat and temperature and basic thermodynamics?
3. Will students critique each other and thereby develop more sophisticated and accurate arguments that support their claims about sinking and floating?

## CONCEPTUAL FRAMEWORK

State and National standards of learning call for an approach to teaching science that incorporates inquiry activities as part of the curriculum (National Academy Press, 1996). The National Research Council (2002) describes five characteristics of an inquiry lesson presentation.

1. Learners are engaged by scientifically oriented questions.
2. Learners give priority to evidence, which allows them to develop and evaluate explanations that address scientifically oriented questions.
3. Learners formulate explanations from evidence to address scientifically oriented questions
4. Learners evaluate their explanations in light of alternative explanations, particularly those reflecting scientific understanding.
5. Learners communicate and justify their proposed explanations.

While implementation of inquiry type activities have been defined several different ways, the main thrust is that students develop the concepts they are learning through examination of data. Martin-Hansen (2002) defines four types of inquiry activities that are commonly used in science classes.

1. Open or Full Inquiry: Students develop their own question and design the investigation which will lead to understanding of an underlying scientific concept.
2. Guided Inquiry: The teacher presents students with a question or situation and then helps the students decide what and how to investigate a concept.

3. Coupled Inquiry: A bridged approach between open and guided inquiry in that the teacher may present the students with a question or topic but then allows the students to take the lead in data collection. The teacher has a role in guiding the students and resolving the final product so that concepts are understood.
4. Structured Inquiry: A traditional step-by-step teacher-centered lab approach. Students collect data in a controlled setting and are lead to conclusions that are pre-determined.

While these definitions are helpful, they are not in universal usage. Shive, Bodzin and Cates (2002) studied 137 chemistry related web sites following a protocol developed by Bodzin and Cates (2001). The study by Shive and colleagues was undertaken to determine "(1) the prevalence of chemistry-related websites currently available on the World Wide Web and (2) to determine their pedagogical and design characteristics" (p. 2). While Shive did not classify inquiry activities, the criteria for whether or not an activity could be considered an inquiry activity was dependent upon whether or not students used evidence to support conclusions. Other criteria included whether or not the evidence was of the same type that would be used by a scientist, and whether or not the conclusions reached by students required "more than simple data analysis and reporting. They must involve reasoning" (Shive et al., 2002 p. 3). While Shive's study is nine years old, it points out that many activities that are advertised as inquiry are little more than 'cookbook' labs that have been adapted to include some characteristics of inquiry.

Deming and Cracolice (2004) describe the need for and benefits of a Peer-Led Team Learning (PLTL) in science classes which uses a Piagetian philosophy to enhance and assist students in moving from concrete reasoning to formal operational reasoning abilities. In his description of a unit which studies the gas laws, Deming stresses the need for students to make sense of data as being true inquiry. These three investigators, Martin-Hansen, Shive et al. and Deming show that the nature of inquiry as it relates to science education is a continuum where many different approaches can be called inquiry.

As Deming and Cracolice (2004) describe their Peer- Lead Team Learning approach, students work in groups which would require communication and 'give and take'. In a larger context, effective teaching of science requires that the teacher take on more of a role of facilitator of learning than the typical lecture. Inquiry learning then takes the form of student directed learning versus the typical teacher directed learning.

As inquiry practices expand, there needs to be a development of tools for students to synthesize and to develop a real authentic learning of the subjects. One of those opportunities is argumentation. Tippett (2009) describes several studies and identified common trends with the different approaches to argumentation. Citing other researchers she lists five important aspects of the growing emphasis on argumentation as a pedagogical tool.

1. Explicit instruction helps students argue more effectively.
2. Professional development helps teachers emphasize argumentation and scaffold it more effectively.
3. Well-established ground rules for acceptable argumentation enable more students to participate in focused argumentation.
4. Explicit Instruction and established ground rules for argumentation promote increased conceptual growth and change.
5. Metacognition skills are related to argumentation skills.

For this study, I will use the Toulmin Argument Pattern (TAP) as described by Simon in her 2008 study. In this framework of argumentation, Toulmin defines an argument as consisting of Claims, Data, Warrants, Qualifiers, Backing, and Rebuttals. Simon defines the terms as follows:

- Claim- Assertions about what exists or values people hold.
- Data- Statements that are used as evidence to support the claim.
- Warrants-Statements that explain the relationship of the data to the claim.
- Qualifiers- Special conditions under which the claim holds true.
- Backings- Underlying assumptions that are often not made explicit.
- Rebuttals- Statements that contradict the data, warrant, backing or qualifier of an argument. (p.279)

Osborne, Erduan and Simon (2004) described a multi-year study to promote argumentation skills, improve teacher implementation of argumentation practices and measure the degree to which those practices improved student performance. Among their findings are several key points. They found that students can improve their ability to support their positions if the skills are explicitly taught. However, the ability to synthesize their positions depends heavily on the knowledge base the students bring to the activity they are studying. They also found that even though teachers may initially fear that confusion in students may result from having to consider multiple explanations or points of view, students can indeed differentiate and make sense of different data streams.

In a study published in 2010, Venville and Dawson described a scenario in which students argued about the socio-scientific implications of informing an expectant couple about a DNA test result that indicted their baby may have the genetic markers for cystic fibrosis. Students then examined the scientific and social implications of whether or not the parents should be informed of the test results. Setting aside the moral questions, the researchers found that in using argumentation, students presented their reasoning with more rational explanations and in doing so increased their subject content knowledge. Other results of this study that are relevant to this project are: specific interventions in how to argue improved students argumentation skills and more research is needed on the effect of argumentation and concept understanding.

Another study of interest is one conducted by Sandoval and Millwood (2005). In this study, one group of students explained how natural selection could explain why some finches from a Galapagos island survived a catastrophe. Another group of students used natural selection to explain how the tuberculosis bacteria developed immunity from antibiotics. Two groups of students studying different concepts were used to show how patterns of arguments change independent of the specific lesson content. The results from this study supported Osborne (2004) in that students need a proper conceptual background to develop arguments. It also found that the process of argumentation can expose incorrect understandings of underlying concepts and this can come about by students challenging each other’s claims.

Jonathan Osborne (2010), published an article in which he summarized the role of collaboration and critique in science education. Central to his thesis is the need for the critique of arguments. Arguments, he claims, need to be presented, justified and defended when challenged. Osborne further cites a 2008 publication by the National Research Council which emphasizes the future need for individuals to be able to participate in ‘critical, collaborative argumentation’.

A problem that becomes apparent in this field of study is the analysis of the arguments presented by students. Furtak, Hardy and Beinbach (2010) used what they termed as Evidence-Based Reasoning [EBR] framework to develop a system of coding that assesses the quality of student arguments. In this study the researchers found among other things that there is no easy or standard coding system. Part of the reason is that it is difficult sometimes to differentiate between what Toulmin defines to be claims and warrants. Furtak etal. further states:

...in a given moment, the students—as co-constructors of arguments in classroom discussions—may provide only the sufficient quality of backing necessary to make their point, and as a result, assessments of their discussions may underestimate students' ability for scientific reasoning. Therefore, users of the framework need to be sensitive to specific instructional objectives of the discourse being analyzed, particularly the issue of which kinds of statement should be supported by evidence and how explicit that support should be. From a formative assessment perspective, teachers listening to students participating in classroom discussions need to make distinctions about which contributions require backing and which do not. So long as constructing some form of argument supported be evidence is shared as an explicit goal within the classroom, it is reasonable to assess students against this standard. (p.192)

Moreover, the context of a particular problem can change the meaning of some of the terms used in the Toulmin Argument Pattern. And lastly, different curricular emphasis changes the concepts that student have been exposed too and have available for their use. As Furtak et al. (2010) described, in the United States curriculum sinking and floating is generally geared to an understanding in terms of relative density and in Germany, buoyancy is emphasized. The difference in emphasis produces different arguments of explanation in both groups. Furtak et al. suggests that future studies should be made in which there are comparisons between the arguments students make and the written assessments students complete. Furtak et al. also cites the Osborne study of 2004 suggesting that "Future iterations of the framework may also involve an additional set of codes that can capture the extent to which student's present ideas that are in opposition with each other" (p.20).

The methods of examining arguments have been studied. Sampson and Clark (2008) surveyed and described characteristics of and frameworks for assessing arguments. They describe the work of researchers using, Toulmin's Argument Pattern and frameworks developed by Zohar and Nemet (2002), Kelly and Takao (2002), Lawson (2003), Sandoval (2005), and others. Each method of analysis has strengths and each has weaknesses. Each method looks in detail at some aspect of argumentation and how arguments are constructed and presented by students. A full description of each is beyond the scope of this study, but a few of the concluding remarks from Sampson and Clark (2008) are important.

While this atomized approach has proven fruitful, future research will hopefully include more holistic considerations of the quality of the arguments students articulate.

This work, however, will require new approaches that examine the structural, conceptual, epistemic and social aspects of argument generation in a more synergistic fashion than looking at each of these aspects independently. (p. 469)

Furthermore, Sampson and Clark (2008) make the assertion that past studies have provided

> ...substantial and valuable empirical foundations for science educators to build upon, more research examining the underlying causes of these patterns and themes will prove valuable in developing new curricular materials, instructional approaches, and technology-enhanced learning environments to promote and support more productive argumentation inside the classroom. (p. 470)

It is this new curricular materials and instructional approach that I am addressing in this study. I will use the Toulmin Argument Pattern as a basis of classifying argument statements. A derivative of the framework of levels as shown in Table 1 and other work described by Erduan, Simon and Osborne and cited by Simon (2008 p.281), will be used for assessing student arguments.

Table 1
*Analytical Framework Used for Assessing the Quality of Argumentation*

| | |
|---|---|
| Level 1 | Argumentation consists of arguments that are a simple claim versus a counter-claim or a claim versus a claim. |
| Level 2 | Argumentation has arguments consisting of a claim versus a claim with either data, warrants or backings but do not contain any rebuttals. |
| Level 3 | Argumentation has arguments with a series of claims or counterclaims with either data, warrants, or backings with the occasional weak rebutals. |
| Level 4 | Argumentation shows arguments with a claim with a clearly identifiable rebuttal. Such an argument may have several claims and counterclaims as well. |
| Level 5 | Argumentation displays an extended argument with more than one rebuttal. |

## METHODOLOGY

My research required six weeks of class time beginning the third week of March and ending the last week of April. To answer my research questions, I designed a process which included pre and post assessments, summative assessments in the form of interviews, surveys and typical chapter tests. These were intended to track improvement in my students' skills in writing arguments and understanding the concepts of study. During the treatment, my students studied the topics of sinking and floating, buoyancy, heat and temperature and basic thermodynamics. The completed activities and artifacts were collected and coded using rubrics to track the development of both the understanding of curriculum concepts, and improvement in the application of characteristics of valid arguments.

## Participants

The subjects of this intervention will be Grade 9 Physical Science students. I selected my 3rd period class which has 17 students with an equal representation of all academic abilities. The mix of boys and girls in this section is determined by the scheduling preferences of the students. Some students elected to take Industrial Arts instead of Art class and that preference determined into which period of my two sections of 9$^{th}$ grade classes they would be placed. For my intervention the selected cohort consisted of 12 girls and 5 boys. The students in the treatment group are almost exclusively Caucasian with one student of Asian heritage, one student of Native American heritage and one student who would be considered mixed race. 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.

## Intervention

The goal of this study is to develop argumentation skills through the use of an activity I have developed called *Prove It!* The study will include measurements of the progression of both verbal and written arguments of curricular concepts along with measurements of improvement in understanding of those concepts. Four units of study from the grade 9 curriculum were used. They are the concepts of density, buoyancy, heat and basic thermodynamics.

The intervention began with instruction regarding the principles and terms used in defining, constructing and analyzing arguments. The initial instructional approach was to define what is meant by the term argument. It was stressed that the word argument for this study is not a disagreement as would be a typical interpretation, but rather a statement meant to convey information and the reasoning by which the interpretation should be accepted. Students were guided through examples of arguments (Appendix A and B). The examples are designed to introduce students to the importance of supporting with data the statements they make. The examples also stress including reasons for why those statements and the data they use are valid. During this direct instruction phase, it was emphasized that terms classifying the constituents of the arguments are to be understood and applied in their own explanations of the concepts they will be studying during this treatment. The examples include arguments dealing with both science related topics (Mendeelev and the Periodic Table) and topics that students may find more relevant to their lives (preferences of types of music).

After the initial instruction and discussion about the importance of complete, unambiguous statements of facts and opinions, and the need to support those facts and opinions with clear backings, we moved on to practicing the classification of argument statements. This was accomplished by having students read and dissect several examples (Appendix C, D, and E). The purpose of this activity was twofold. First, it further reinforced the introduction of the concepts of argumentation and terminology of arguments and secondly it gave students practice and feedback in the skills they will need to use as they apply the ideas they have learned. When the activity was run, they used the argumentation classifications in defense of the ideas they hold about the concepts of study such as buoyancy and heat and temperature.

The activity *ProveIt* was designed so that peers will critique each other and provide feedback to each other and thereby increase the motivation to improve their own statements and reasoning. The activity began with an open-end scenario related to the concepts we are studying. Students read the scenario and applied the concepts of argumentation in their written response (Appendices I, J, K, L, R, W, X). After the written response, they had to break down the argument into the separate characteristics such as claim, evidence, warrant etc. At this point students scored their arguments according to the instructions (Appendix Y). At the completion of these activities, the students randomly switched papers and examined the responses of other students. They then examined their classmates' argument and entered their own suggestions and improvements. After this, they completed scoring their worksheets.

Data Collection

Using the ideas of previous researchers such as Toulmin (2007), Simon, Erduran and Osborne (2006), Osborne, Erduran and Simon (2004), Furtak, Hardy, Beinbrech, Shavelson and Shemwell (2010), Sandoval and Millwood (2005) and Sampson and Clark (2008), I devised a rubric as shown in Table 2 for coding student responses regarding the use of characteristics of argumentation when engaged in the activities of my study.

Table 2
*Rubric for Coding of Student Argumentation*

| | Correct for the scenario and linked to the initial question | Correct for the scenario but not linked to the initial question | Incorrect for the scenario but linked to the initial question | Incorrect for the scenario and not linked to the initial question | Item is missing |
|---|---|---|---|---|---|
| Claim | 4 | 3 | 2 | 1 | 0 |
| Data | 4 | 3 | 2 | 1 | 0 |
| Warrant | 4 | 3 | 2 | 1 | 0 |
| Backing | 4 | 3 | 2 | 1 | 0 |
| Qualifier | 4 | 3 | 2 | 1 | 0 |
| Rebuttal | 4 | 3 | 2 | 1 | 0 |

For tracking improvement in conceptual knowledge, I used the rubric as shown in

Table 3
*Rubric for Curriculum Concepts*

| | Present | Mostly present | Somewhat present | Missing |
|---|---|---|---|---|
| Vocabulary use | 3 | 2 | 1 | 0 |
| Detail of description | 3 | 2 | 1 | 0 |
| Explanation of relationships of material | 3 | 2 | 1 | 0 |
| Accuracy of explanation | 3 | 2 | 1 | 0 |

Each unit of study had a multi-step data collection process. The treatment process consisted of a pre-treatment formative assessment and interview along with direct instruction in the curricular concepts of the units under study. Then students completed an activity where they applied the principles of argumentation and critiqued the application of the characteristics of argumentation by their peers. After this, they completed formative assessments and interviews that mirrored the pre-activity assessments.

Data Collection Strategies

All the students in the 9$^{th}$ grade Physical Science class section I selected participated in the activities of the study; however eight students were tracked during this study to measure the impact of this treatment. These eight students were selected so that two were from a high performing set of students, four were from typical or 'average' students and two were from a low performing set of students. They were selected based on past grades and class performance.

Step 1 of each unit began with an interview of the eight students. The interview established a baseline of the understanding they held about the concept. Following the interview, Step 2 consisted of the students completing a formative written assessment related to the concept. These were coded with both rubrics to track progress in written arguments. During Step 3 students participated in an activity based on the principles of Structured Inquiry. During this step, they received direct instruction on the concepts of each unit of study (density, buoyancy etc.) through typical means such as lectures, textbook reading, worksheets etc. This gave them a degree of background knowledge which they can use during the *ProveIt!* activity. This followed Sandoval and Millwood

(2005) and Osborne et.al (2004) who found that students need appropriate prior knowledge of the subject before they can make arguments. Step 4 included the completion of the structured inquiry activity where they made their arguments and critiqued their peers. Step 5 was a post interview of the previously selected eight students that mirrored the pre-interview and the formative assessments.  The pre and post formative assessments and interviews established benchmarks for measuring improvement in both the verbal and written aspects of their arguments. The artifacts collected from the *ProveIt*! activity provided data for measuring improvement in argumentation skills. These activities supported and provided data to answer the focus and sub-questions shown in the triangulation matrix, Table 4.

Table 4
*Data Triangulation Matrix*

| Focus Question: Can argumentation skills be learned with a teaching strategy that includes direct instruction and peer-critiquing methods? | | | |
|---|---|---|---|
| Sub Questions | Data Source | | |
| Sub Question 1: Will activities emphasizing argumentation lead to more sophisticated explanations of curriculum concepts by students? | Pre-treatment formative assessments | Artifacts from activities | Post-treatment formative assessments |
| Sub Question 2: Will students effectively critique each other? | Artifacts from activities | Post-treatment interview | Post-treatment survey |
| Sub Question 3: Will argumentation assist students in explaining relationships between scientific concepts and what has been observed. | Pre-treatment formative assessment | Post-treatment formative assessment | Post-unit summative assessment essay |

<u>Unit 1 Density</u>

The unit on density commenced with the formative assessment ‘Floating Balloon’ (Appendix F) followed by the interview of the eight students previously selected (Appendix G and H).  Following completion of these activities the students were assigned the task of designing a ‘Mini-Sub’ (Appendix I). During the time the students were designing and solving the task, the class completed the typical activities of the curriculum including lectures on the concepts of density and sinking and floating. The activity *ProveIt!* (Appendix J and K) was completed next. During the activity, students read the prompt and wrote an explanation including their claims, warrants rebuttals etc. This was retained for analysis later. I used these to look at the amount of detail they included along with appropriateness of the statements they included. I also looked for the amount of detail as well as whether or not the critiques contained vocabulary, explanations of relationships etc. After the writing of the arguments and critiques were complete, the students tested their submarines in an aquarium that had been set up in the classroom. Following the testing of their designs, each student was interviewed again (Appendix G and H), and they again completed the formative assessment (Appendix F).

Unit 2 Buoyancy

The sequence of each subsequent unit followed the same pattern as established in the Density unit. There was an interview (Appendix N), and a formative assessment (Appendix O) before the activity. For this unit the students constructed a Cartesian diver using plastic pipets, a threaded metal nut and a two liter soda bottle. After using the bottles and seeing the effects of pressing and releasing the sides of the bottle, the students completed the activity *ProveIt!* in an effort to explain the principles that govern the behavior of the plastic 'diver'. Again the activity sheets were retained for analysis and coding. The students were interviewed again and again, they completed the formative assessments both with the same format as the initial interviews and formative assessments. At the conclusion of the density and buoyancy units, a typical summative assessment was given including multiple choice, and completion questions.

Unit 3 Heat

The heat unit began with an interview (Appendix P) and a formative assessment (Appendix Q). Typical instruction took place using the textbook, lectures worksheets etc.

which defined terms such as heat, temperature, heat flow and molecular activity. The activity the students considered consisted of a block of metal and a block of wood both at room temperature (Appendices R, S, and T). After touching each block the students noticed that the metal felt noticeably colder while the wood would felt noticeably warmer than the metal. The question the students considered is: “why does one object feel colder than the other if they are both at room temperature?” The *ProveIt!* activity was then completed, and the worksheets retained. After the activity, the students were interviewed again and given the same formative assessment as before.

Unit 4 Thermodynamics

The thermodynamics unit began with an interview (Appendix U) followed by the formative assessment Mixing Water (Appendix V). Classroom instruction followed using the text, lecture, and worksheets. The activity (Appendices W and X) for this unit required students to defend the choice of material for pots and pans using the concepts of specific heat. As before, the activity sheet was retained and coded using the rubrics. After the completion of their argument and critique, they again completed the formative assessment and the post-interview using the same formats as before. When all the activities were completed the students completed a summative assessment consisting of multiple choice and an essay question. The essay question was scored using the same rubrics.

## DATA AND ANALYSIS

I began this study wondering if the skills of argumentation could be taught using direct instruction complimented by regular peer-critique activities in a classroom setting.

A broad statement of the findings of this study indicates that there is a positive effect from the treatments in this study. During the course of the project, students were interviewed, assessed with formative assessments, critiqued by peers and scored by both themselves and peers. I selected three sub questions that supported the main focus question which is: Can argumentation skills be learned with a teaching strategy that includes direct instruction and peer-critiquing methods?

Argumentation activities lead to more detailed explanations of curriculum concepts.

For the collection of quantitative data related to student use of the characteristics of argumentation, I devised the Rubric for Coding of Student Argumentation (Table 2). At the completion of an activity, the written artifacts were collected from the students. The artifacts were then given to a colleague who took off the student names and wrote a coded identifier in the place of the name. This assured anonymity when I scored the responses. The rubric was used to score the various categories of arguments such as use of claims, data, and warrants, backing statements, qualifiers and rebuttals. I used a Likert scale from 0 to 4. The descriptors ranged from ‘Correct for the scenario and linked to the initial question’ which would earn a score of 4, to ‘Incorrect for the scenario and not linked to the question’, which would earn a score of 1 to ‘Item is missing’ which would earn a score of 0. The scores for each activity for the eight students were entered into an Excel spreadsheet and each category was then averaged to give a composite average score for that activity and that item. In doing this, it was possible to track overall improvement for each argument characteristic. A higher average score indicated more students appropriately used that category of argument. For example; in the thermodynamics unit (Table 5), the average score for the pre-activity formative assessment for the use of data was 2.75 (on a scale of 0 to 4) with a standard deviation of 1.04 and this score improved to 3.25 with a standard deviation of 1.04 in the post-activity formative assessment.

Table 5
*Thermodynamics Argumentation Characteristics* (*n*=8)

| | Claim | Data | Warrant | Backing | Qualifier | Rebuttal |
|---|---|---|---|---|---|---|
| Thermodynamics-Pre | 3 | 2.75 | 2.5 | 1 | 0 | 2 |
| Thermodynamics Activity | 4 | 2.88 | 2.88 | 2 | 1 | 1.13 |
| Thermodynamics-Post | 2.75 | 3.25 | 3 | 1.25 | 0.5 | 1 |
| Percent Increase/Decrease | -9.09 | 15.38 | 16.67 | 20.00 | 100.00 | -100.00 |

This indicates that students used more data appropriately in their arguments after completing the *ProveIt*! activity. In addition, Table 6 shows clearly that there were dramatic increases in curriculum knowledge in the same unit of study.

Table 6
*Thermodynamics Curriculum Concepts* (*n*=8)

| | Vocabulary | Detail of Description | Explanation of Relationships | Accuracy of Descriptions |
|---|---|---|---|---|
| Thermodynamics-Pre | 0.88 | 1.63 | 1.75 | 1.5 |
| Thermodynamics Activity | 1.25 | 1.63 | 1.5 | 1.38 |
| Thermodynamics-Post | 1.14 | 1.43 | 1.43 | 1 |
| Heat Test | 2.38 | 2.5 | 2.5 | 2.13 |
| Percent Increase/Decrease | 63.03 | 34.80 | 30.00 | 29.58 |

While some of this increase can be attributed to direct instruction consisting of lectures, worksheets etc., during the unit of study, the scores still increase between the post-formative assessment and the summative unit test. No additional teacher-lead instruction occurred between those two events.

In the first unit of study –Floating- Table 7 shows a decline in use of curriculum concepts. This was the unit when students were first introduced to writing arguments. A possible explanation is the confusion students encountered with the new terminology and expectations of including new approaches to the written assignments. However, the trend of increases in use of more formal vocabulary and explanations was consistent as shown in Table 8 and Table 9.

Table 7
*Floating Curriculum Concepts* (*n*=8)

| | Vocabulary | Detail of Description | Explanation of Relationships | Accuracy of Descriptions |
|---|---|---|---|---|
| Formative-Pre | 0.75 | 0.88 | 0.88 | 0.75 |
| Submarine Activity | 0.38 | 0.38 | 0.38 | 0.38 |
| Sinking and Floating Activity | 1.88 | 2.13 | 1.88 | 1.88 |
| Formative-Post | 0.63 | 0.75 | 0.63 | 0.38 |
| Percent Increase/Decrease | -19.05 | -17.33 | -39.68 | -97.37 |

Table 8
*Buoyancy Curriculum Concepts* (*n*=8)

| | Vocabulary | Detail of Description | Explanation of Relationships | Accuracy of Descriptions |
|---|---|---|---|---|
| Buoyancy-Pre | 0.9 | 0.79 | 1 | 0.98 |
| Buoyancy Activity | 2.71 | 3 | 3 | 3 |
| Buoyancy-Post | 1.88 | 1.88 | 2 | 2 |
| Fluid Test | 1.63 | 1.75 | 1.75 | 1.5 |
| Percent Increase/Decrease | 44.79 | 54.86 | 42.86 | 34.67 |

Table 9
*Heat Curriculum Concepts* (*n*=8)

| | Vocabulary | Detail of Description | Explanation of Relationships | Accuracy of Descriptions |
|---|---|---|---|---|
| Heat-Pre | 1 | 1.13 | 1 | 1.25 |
| Heat Activity | 2.13 | 1.88 | 1.75 | 1.5 |
| Heat-Post | 1.38 | 1.88 | 1.38 | 2.25 |
| Percent Increase/Decrease | 27.54 | 39.89 | 27.54 | 44.44 |

Written arguments consistently showed increases in the use of vocabulary, detail, etc. as measured by the rubric. Verbal explanations, however, as collected during the interviews, showed only a small difference in the use of those characteristics. When comparing pre and post treatment interviews, only marginal changes could be noted. During the pre-treatment interview of the Heat unit, for example, (Appendix P), a student responded to the question; 'What does a refrigerator do so that water can freeze?' The students' response was: 'It lowers the temperature by blowing cold air.' At the post-treatment interview, the same student answered the same question with; 'It blows cold air and takes away heat'. The answer is better in that the student recognizes the loss of heat energy as a factor. However, the response lacks vocabulary, detail and any explanation of the relationship between the energy of the water molecules being removed from the water and the freezing of the water. If students were transferring their improvement in argumentation to verbal answers as well, one would expect a more robust answer. With a few exceptions, this trend continued; improvement in written explanations without much change to verbal explanations.

Students find peer-critiques helpful.

To measure student attitudes regarding this study's methods of instruction in argumentation, personal feelings towards argumentation and its effect on their own learning, I administered the Argumentation Survey (Appendix Z). The survey probed several areas of concern including attitudes about argumentation in general and the need for it, to their perceived ability, to their feelings about keeping score during the activities and the value of reading critiques of their work and writing critiques about others work. The Likert scale used ranged from 5 for 'Strongly Agree', 4 for 'Agree' to the statement, to 3 for a 'Neutral' response, 2 for 'Disagree' to 1 for a 'Strongly Disagree' opinion. Those responses were entered into an Excel spreadsheet and student responses were averaged for each item.

To answer my second sub question- 'Will students effectively critique each other?' I make the claim that peer critiques of arguments can be effective in improving the arguments put forth by students. For this study, peer critiquing occurred on four separate occasions. Each structured inquiry activity (Appendices J, K, L, M, O, W, X) was selected or written so that students had to make a claim and defend it with vocabulary and concepts from the unit we were studying. After reading the scenario, students wrote their argument on the worksheet, then selected statements from their argument, and categorized them as to whether they were claims, warrants, data etc. These responses were then randomly given to classmates who read the argument and on a separate line, either corrected conceptual errors with their own suggestions or reclassified the parts they considered as being in the wrong category.

The Sinking and Floating activity (Appendices I & J), in which students were to argue as to why a film canister submarine was able to either descend or rise under its own power provides a typical example of helpful critiques. A student (M-10) wrote the claim as ‘Emily’s sub worked’. While the student considered it to be a claim, it is more of an observation. It lacks detail or statement of the reason why the sub worked. The student who critiqued the argument suggested the statement be changed to; ‘Emily’s sub descended, picked up a magnet and returned to the surface.’ The student (M10) then supported the initial claim with the data statement ‘the sub sank at first; causing the sub to float’. The correction offered by the critique writer was; ‘the sub sank, then the density changed, causing the sub to rise again.’

Peer critiques also offer the chance to reinforce the objectives of the process of breaking down an argument. One student in particular, M-2, consistently scored low in skills and conceptual understanding. During the thermodynamics activity (Appendices W & X) where students select the better material for a cooking pot, he used as his entire argument:

> “Terry has the better idea with copper because it keeps in the energy more than aluminum”

However, he listed as his claim; ‘copper is a better conductor of heat’. He then listed as his data as; ‘stove added 20,000J and the pans weighed 500g’. Both statements may be true and accurate but were not part of his original argument. This was pointed out by the student who critiqued his paper. This student then had the opportunity to learn and improve future arguments.

Sometimes the critiques improve the amount of detail or the grammar of the argument. Returning to the thermodynamics activity, a student wrote the claim as: ‘They should get copper pans.’ The critique writer correctly suggested a more detailed statement by referring to a specific person from the written scenario, writing ‘Terry was right, they should get copper pans.’ This type of critique, where more detail is suggested was common for other students as well. Student F-14 wrote a qualifier for the thermodynamics activity that said: ‘that means they will heat food more evenly’. Student M-10 suggested more detail when he wrote ‘that means that aluminum pans will heat food more evenly’.

In each case, students get feedback from peers and have a new perspective on how others construct arguments. At the conclusion of the treatment the students were interviewed (Appendix AA) as to their feelings and attitudes about the process of having their classmates critique their work. When asked if the critiques helped or hindered the improvement of their own arguments, responses were generally favorable as to the critiques being helpful. Some representative responses are:

“It helped me expand what I was writing and helped me understand the terms.”

“I got different ideas about the material and how to write an argument.”

“It showed me that certain words can strengthen and defend my argument.”

“It showed me where I could go wrong in mine.”

One student even reported that she had used the techniques learned in my class to other classes she was taking.

Not all students had positive responses however. One student said that the critiques “didn’t help because they [the person writing the critique] got stuff wrong.” Although, this too could have be seen as a learning opportunity for the student because it gives another perspective to students about what is appropriate and what is not appropriate to include in an argument.

One aspect of the critique by classmates that concerned me was that the students in our small school know each other so well, I was afraid that they would be hesitant to correct each other. When I asked Question 3 of the survey, ‘How did the knowledge that your arguments would be looked at by classmates affect how you wrote your argument?’ I was pleased that the typical responses were positive, such as:

“I tried to make it so they would understand it too.”

“It made me want to try harder so I could show that I was completely right.”

“I tried to write it pretty good so I wouldn’t be criticized.”

And finally, “I explained it more thoroughly than if it were somebody I didn’t know”. I followed that with the question, ‘Why?’ The student’s answer- “Because I have to see them every day”.

<u>Argumentation assists students in formulating ideas that explain relationships between scientific concepts and what has been observed.</u>

To address my third sub-question, I make the claim that argumentation requires students to use accurate explanations that explain relationships between observations and curriculum concepts and this is facilitated by argumentation. Figure 1 shows that the explanation of relationships in written arguments for the initial peer-critique activity (Submarine activity) and summative unit tests, increase over time.

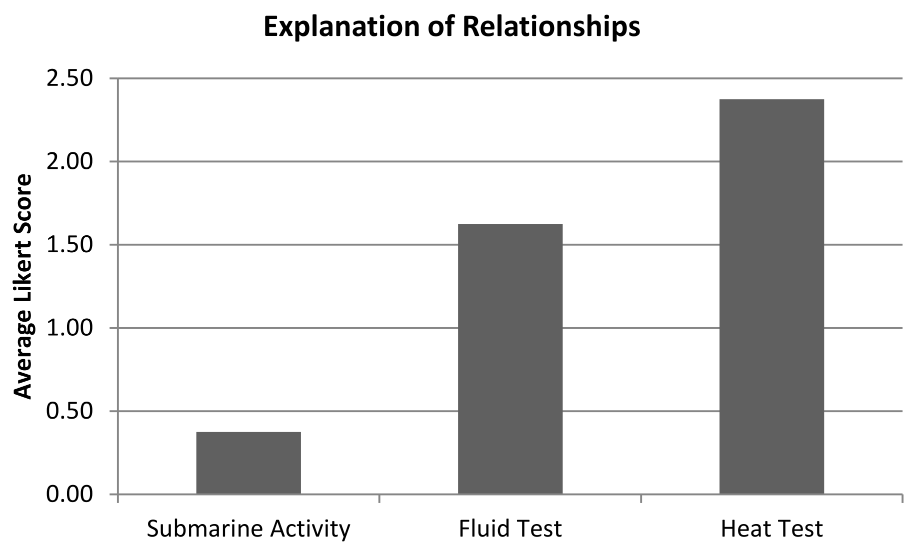


*Figure 1.* Explanations of Relationships.

Since there was little direct instruction in argumentation techniques during the units of study, the improvement can be explained by the use of peer-critique along with additional practice in writing arguments. This is substantiated by the Argumentation Survey responses for the item ‘Reading a critique of my argument helped me write better arguments’. This survey item produced a Likert score of 3.63 out of a possible score of 5 with a standard deviation of 1.19. Another item on the survey; ‘Critiquing someone’s argument helped me improve my arguments’ had a Likert score of 3.5 and a standard deviation of 0.93. Both scores indicate positive responses to the value of having their work critiqued and having to critique other students.

The Rubric for Curriculum Concepts (Table 3) was used to track the use of curriculum concepts such as vocabulary use, detail of description, explanation of relationships of material, and accuracy of explanation. A Likert scale on this rubric tracked the usage of vocabulary, accuracy of description, explanation of relationships and detail of descriptions. The scale ranged from a 3, indicating the presence of appropriate use of vocabulary, accuracy of explanation etc. A score of 2 indicated that the item was mostly present; a score of 1 meant the item was somewhat present; and a score of 0 indicated that the item was missing from the argument. As in the rubric for argumentation, the higher the average score, the more appropriately the students were using those concepts. For example; an average score of .75 with a standard deviation of 1.39 in the ‘accuracy of description’ category in the curriculum concepts rubric for the submarine activity indicated that not many students were accurate in their description of the concepts of fluid behaviors. However, that score increases at the end of the unit to an average of 1.5 with a standard deviation of 1.60. While this is well below the best possible average score of 4, it does indicate an improvement in accuracy of the explanations.

Explanations of relationships increased from .38 in the submarine activity to 1.75 in the summative Fluid test essay responses. The thermodynamics activity had an average of 1.5 while the summative essay test rose to an average of 2.5. Again, there was little direct instruction in argumentation other than reminders to include the characteristics of arguments during the activities, so improvement, while possibly due to practice it can also be attributed to peer critique as cited in the survey results.

## INTERPRETATION AND CONCLUSION

This project set out to investigate whether or not peer-critiques of student arguments would support student learning. I collected data in the form of interviews, formative assessments, summative assessments and surveys. What I found was that a teaching strategy that includes peer critiques of student arguments can indeed improve both the quality of a student's argument and the understanding the student has about curricular material.

Two examples of increases in the ability to formulate a cogent argument can be seen in Figure 2 and Figure 3.

Pre-treatment essay question: Picture a ball traveling at a constant speed around the inside of a circular structure. Is the ball accelerating? Explain your answer.

Student M-10 response: No. Because if the ball was truly moving at a constant speed and moving in the exact same circular path, its speed would remain constant and not accelerate.

Post-treatment essay question: Explain the role of density in the formation of convection currents.

Student M-10 response: Density plays a large part in the formation of convection currents. The principle is that if an object is denser than water it will sink, and vice versa if it is less dense. So, therefore, the same rules apply with heat and water. If the heat produced through convection is denser than water, it will sink and eventually circulate with a less dense wave of heat, producing a convection current.

*Figure 2.* Student M-10 increase in ability to form an argument.

Pre-treatment essay question: Picture a ball traveling at a constant speed around the inside of a circular structure. Is the ball accelerating? Explain your answer.

Student F-16 response: Yes, because all the curves it travels around cause the acceleration to continue. Eventually it will stop, but the change in direction will cause acceleration.

Post-treatment essay question: Explain the role of density in the formation of convection currents.

Student F-16 response: Density plays a key role in convection currents. Density is caused by the particles of matter. It is important because without the density the air or fluid would not rise and sink. That means that less dense things float up and more dense things sink down. Not only that but the density causes convection currents to form a loop or circular motion. Without convection currents heating and cooling of your house wouldn't be possible.'

*Figure 3.* Student F-16 increase in ability to form an argument.

Setting aside some of the inaccuracies and oversimplifications of the responses, it can be seen that both students have improved their arguments by using specific statements backed by accurate data. Student M-10's first statement included the inaccurate statement: 'if the ball was truly moving at a constant speed and moving in the exact same circular path, its speed would remain constant and not accelerate.' In his later response, he included the accurate statement 'if an object is denser than water it will sink'. In the response to the motion question his claim was a one word response, 'No', with little in the way of backings, warrants or qualifiers. In his later response regarding heat, his claim was the complete sentence 'Density plays a large part in the formation of convection currents.' He then presented the statement 'if an object is denser than water it will sink' as data.

Student F-16 followed much the same pattern in that her claim in the motion test response was a single word; 'yes'. One could make a case that she included data in her response in the statement '...the change in direction will cause acceleration.' It could also be contended that her statement ‘all the curves it travels around cause the acceleration...’ as a backing statement to support the data statement. While much more detail could have been cited, she has the bare bones of an argument. In the response to the heat test prompt she has gone into much more detail and supported her claim with more data and warrants and qualifiers. She included supporting statements such as ‘without density the air or fluid would not rise and sink’ and ‘less dense things float up and more dense things sink down’, and ‘density causes convection currents to forma loop or circular motion’.

Taken together, this shows an improvement in the detail included in arguments, more accurate understanding of the concepts and a more thorough explanation of the thinking of the student.

Argumentation is becoming more and more of a marker for producing students who can think critically, analyze data, and justify their conclusions. All these skills will become more important in the coming years.

This study demonstrates that the understanding of how to explain thoughts in a clear and cogent manner depends on the citing of evidence, explaining why the evidence is important and considering possible rebuttals. As cited in the previous examples, students seemingly have come to a greater appreciation of what it takes to make their thoughts known to others and they have learned from others how to accomplish the transmission of their knowledge.

Overall, this study describes a teaching strategy of direct instruction, peer critiques and the use of open-ended scenarios with no easy answers to develop the skills students need to synthesize information and justify their claims. It produces students who can at least begin to make claims, cite evidence and explain the importance of the evidence.

Future study could include developing a game from this strategy that will be more engaging to students. In this study, students scored their responses and critiques, as they might in a game, however they did not find that to be complimentary to the task so it largely was abandoned.

## VALUE

This project is just the starting point in developing a strategy to teach argumentation using peer-critiques. The studies immediate value is that it taught one class of $9^{th}$ grade science students the basics of how to put forth a claim and back that claim with evidence. It was largely successful in developing the basic skills of argumentation in the explanation of scientific concepts. In addition I was able to identify several areas in need of improvement. I began with the idea of creating a game that would use a competitive approach of keeping score while writing arguments during peer critique. The idea was met with enthusiasm by the students when we first started. However, I quickly learned that not only do students need modeling before they begin; they need to be clear in their understanding of the vocabulary of arguments. Many students had trouble grasping the meaning of terms like warrant and backing and how they could be identified and why they were important, and how they could be included in what they wrote. So, before a game can be played, the students need activities where they learn the basics of argument construction. This is the importance of an activity like the one described by this study. Future development of a game could have a positive impact because a typical lecture, worksheet method of teaching is as many students commented, boring, and leads to uninterested students who do not acquire these important skills.

The value to me as an educator is that I have another method to increase student achievement. I am confident that my results, while with an admittedly small sample of students, produced positive results. I make no claims about the generalizability of my findings other than to say that the positive effects demonstrated were consistent throughout each unit of study. Other researchers may find more valuable techniques than my approach, but I am confident that I have shown that peer critique is at least a valid form of teaching argumentation and that it deserves further study. In conducting my study, I found that unexpected happenings do occur that can divert or change the course of the study. I cite the initial intent of creating a game and keeping score. While I did have the students keep score, the responses to items number five and six on the final Argumentation Survey (Appendix X) shows that students did not find scoring to be helpful. Item five asked for a response to the prompt; ‘I liked the idea of keeping score.’ Student responses averaged 2.6 and a standard deviation of 0.77 which is between the ‘Neutral’ score of 3 and the ‘Disagree’ score of 2. Item six asked for a response to the prompt of ‘Keeping score helped me improve my arguments.’ This too produced an average response of 2.6 with a standard deviation of 0.92. Perhaps with more of a game as was suggested by a couple of students, keeping score would improve engagement and enjoyment of learning.

The value to the student is that they have another method to increase the understanding of the material they study, not just in science class but any class. They also develop skills to be critical thinkers. This comes from the fact that they must examine what they think about a topic and they must think about the topic while they look for supporting statements for their claims. They must evaluate those statements for accuracy and relevancy. They must anticipate counter arguments and buttress what they say with relevant evidence and proper applications of underlying concepts especially when constructing an argument about scientific topics they study in class. One particular advantage of this instruction comes from a student who reported to me at the end of the treatment that she had used these characteristics while writing an essay for another class. Presenting ideas while using evidence and backing up that evidence is a skill that students will use over and over again no matter what direction they take in life.

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# APPENDICES

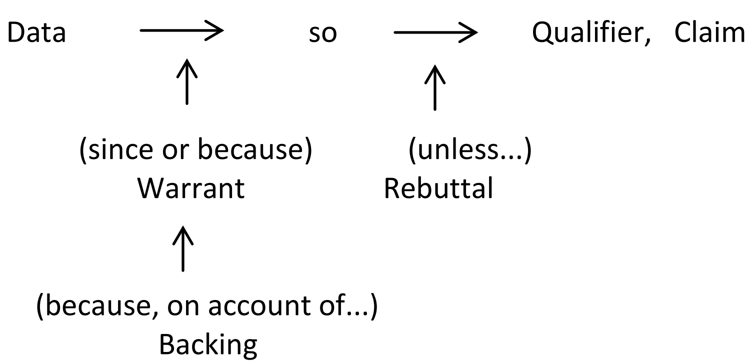
# APPENDIX A

ARGUMENT LESSON PREFACE PAGE 1

## Argument Lesson Preface page 1

When you make an observation about something, there are many ways of expressing yourself. We see it every day. When listening to a song with a friend, you could say "I love this song". Your friend may or may not agree with you. Your friend may think you like the song because you like everything the artist sings, or because of the video or because it was used in a good movie. You might say I love this song because my boyfriend/girlfriend likes this song too." Or you might say, "I like this song because it reminds me of my boyfriend/girlfriend and I won't see him/her for another week."

In each case, you present an argument. Arguments are not necessarily disagreements or fights. Arguments are positions you take based on what you know. When you take a position, particularly in this class, it is important to provide some reason why you have that opinion. It is important to let others know why you have that opinion. In the statement, "I love Lady Gaga's new song", there are no reasons why you love the song. It is just a claim that can lead the person you are with to make assumptions about you and your taste in music. If you were to say, "I love Lady Gaga's music, and this is one song I love", you have provided a foundation for saying that you really like this song. You could further expand your statement and say: "Because I like pop music, especially Lady Gaga, I love this song." Or you could really explain yourself and say, "<u>Because I like her voice and lyrics, I love the new song by Lady Gaga. It makes me want to write a song like it and no other song does that. Since she is so talented and such a good musician, unless I can develop a better style, I want to write like her.</u> "The different parts of this argument can be classified and examined. The different classifications are: claims, data, warrants, backings, qualifiers and rebuttals. The more data, warrants etc. that you have in your argument, the clearer and stronger your argument becomes. For now, let's look at the argument we have for this song. A guy named Toulmin came up with a pattern for looking at arguments;



# APPENDIX B

## ARGUMENT LESSON PREFACE PAGE 2

Argument Lesson Preface page 2

How to classify an argument:

1. Find the claim. Claims are words or phrases that are parts of declarative sentences. ex. ‘this will happen’, ‘the atomic number is’
2. Find the data. This doesn’t need to be a number, but it has to be reason for making a claim.
3. Look for warrants. Warrants might come after words like ‘since’ or ‘because’.
4. Identify backings. Backings could be in phrases starting with words such as ‘because’ or ‘on account of...’
5. See if there are Qualifiers. Qualifiers tell you how strong a warrant is.
6. See if there are any Rebuttals. Rebuttals are things that could make you not accept a warrant.

Let’s look at the parts of our previous argument:

“Because I like her voice and lyrics, I love the new song by Lady Gaga. It makes me want to write a song like it and no other song does that. Since she is so talented and such a good musician, Unless I can develop a better style, I want to write like her. “

We can classify the parts of our argument like this:

Claim-‘I love the new song’ The claim is what comes from the data
Data-’Because I like her voice and lyrics’ Data provides a reason for our claim.
Warrant-‘It makes me want to write a song like it’ Warrants support a claim.
Backing-‘no other song does that’. Backings provide a reason for accepting the warrant.
Qualifier-‘no other song does that’ Qualifiers tell how strong the warrant is.
Rebuttal-‘Unless I can develop a better style, I want to write like her.’

# APPENDIX C

ARGUMENT LESSON PAGE 1

## What is an argument?

An argument in this class is not a disagreement. It is not a debate. An argument is the way you make a statement about something. It is how you use evidence or data to support what you claim is true. For example: If you want to go to Fargo to go shopping you could tell your parents “I want to go to Fargo”. Now, the first thing they might say is “Why?” or they might just say “no.” You may then get into an argument with them, but that is a different type of argument. For our purposes, an argument that you may use to actually get to Fargo could go something like this.

“There was a commercial for a sale at Aeropostale in Fargo. Since I want to save money, and because sales mean lower prices, I need to go to the mall. If I find a jacket on sale I can afford to buy it with my own money.”

Now in our use of ‘arguments’ there are certain terms we can use to really understand what was said. The terms we use will be the following:

Data-this provides some reason for making a claim.
Warrants-these provide the foundation for the claim you are going to make.
Claim-the thing that results from the data.
Backing-this provides a reason for accepting that the warrant has merit.
Qualifier-this helps to strengthen the warrant.
Rebuttal-this is what can disprove or invalidate the warrant.

So let’s look at our example and classify the parts of the argument.

Data-‘There was a commercial for a sale at Aeropostale’.
Warrant-‘Since I want to save money’
Backing-‘because sales mean lower prices’
Claim-‘we need to go to Fargo’
Qualifier-‘If I find a jacket on sale I can buy it with my own money.’

Of course one form of a rebuttal from your parents may be; ‘but for you to save money will cost me a lot of time and gas money.’ You could put a rebuttal in your original argument by explaining how the cost of gas would be offset by the savings on the jacket.

So the nice thing about a well-crafted argument is that you support your claim with reasons why others should believe or accept what you say. It is more likely that you will get others to believe you or do what you need than if you just say “I want to go to Fargo.”

# APPENDIX D

ARGUMENT LESSON PAGE 2

Argument Lesson page 2

Now see if you can classify the parts of the following:

1. The girls basketball team will play Ada-Borup  High School on Thursday and they will win because three of their players are sick with the flu. If they are still sick on Thursday, the backup squad will play and they aren't very good players.

Data___________________________________________________________________________

Warrants________________________________________________________________________

Claim__________________________________________________________________________

Backing_________________________________________________________________________

Qualifier________________________________________________________________________

Rebuttal________________________________________________________________________

2. Since elements have properties that are similar, Mendeleev found a way to organize the periodic table. Because some elements react similarly, based on their electron arrangement, he could begin to see a pattern.

Data___________________________________________________________________________

Warrants________________________________________________________________________

Claim__________________________________________________________________________

Backing_________________________________________________________________________

Qualifier________________________________________________________________________

Rebuttal________________________________________________________________________

Does this example have every part of an argument? How could you rewrite the argument about Mendeleev to make it stronger?

______________________________________________________________________________

______________________________________________________________________________

______________________________________________________________________________

APPENDIX E

ARGUMENT LESSON PAGE 3

3. Cars accelerate because a force acts on the tires and the tires push on the road which pushes the car.

Data___________________________________________________________________________

Warrants_______________________________________________________________________

Claim__________________________________________________________________________

Backing________________________________________________________________________

Qualifier______________________________________________________________________

Rebuttal_______________________________________________________________________

Does the statement have every part of an argument? How could you rewrite the argument about cars accelerating to make it stronger?

_______________________________________________________________________________

_______________________________________________________________________________

_______________________________________________________________________________

4. Two objects of different mass will hit the earth at the same time.
Data___________________________________________________________________________

Warrants_______________________________________________________________________

Claim__________________________________________________________________________

Backing________________________________________________________________________

Qualifier______________________________________________________________________

Rebuttal_______________________________________________________________________

Does the statement have every part of an argument? How could you rewrite the argument about cars accelerating to make it stronger?

_______________________________________________________________________________

# APPENDIX F

FLOATING BALLOON

Floating Balloon Name________________________

Shemal has an uninflated balloon. He fills the uninflated balloon with a gas and ties it closed. When he lets go, the balloon floats up into the sky. Shemal wonders what happens to the mass of the uninflated balloon compared to the inflated, floating balloon. What do you think? Circle the answer that best matches your thinking.

The floating balloon has more mass.

The floating balloon has less mass.

The mass of the uninflated balloon and the floating balloon is the same.

Describe your thinking. Provide an explanation for your answer.

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Adapted from: Keeley, P., Eberle, F., & Dorsey, C. (2007). Uncovering student ideas in science, vol. 3: Another 25 formative assessment probes. Arlington: NSTA Press.

# APPENDIX G

DENSITY STUDENT INTERVIEW QUESTIONS PAGE 1

Density Student Interview Questions Page 1

Questions NAME____________________________

1. Why do some objects sink and some objects float?

____________________________________________________________

____________________________________________________________

____________________________________________________________

____________________________________________________________

2. What is the definition of the word ‘heavy’?

____________________________________________________________

____________________________________________________________

3. What is the definition of the word ‘light’?

____________________________________________________________

____________________________________________________________

4. Why does a ball of clay sink, but a boat-shaped piece of clay float?

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____________________________________________________________

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____________________________________________________________

5. In the classroom there are two Cartesian divers on the front table. Why does one Cartesian diver shoot up to the surface while the other floats up more slowly?

# APPENDIX H

DENSITY INTERVIEW QUESTIONS PAGE 2

Density Student Interview Questions Page 2

6. Define the term ‘density’.

7. If an object sinks in water (liquid A), but floats in another liquid (liquid B), what can you say about the density of liquid B? Can you give the density of liquid B any kind of numerical value?

8. At the beginning of the lessons, I placed cans of Diet Coke and regular Coke in the tank. The Diet Coke floated and the regular Coke sank—why?

# APPENDIX I

MINI-SUB INSTRUCTIONS PAGE 1

Mini-Sub Instructions page 1

MINI-DIVER Names of Group Members________________________
________________________

**Your Task:**

Design a 'submarine' that will retrieve a small magnet from the bottom of a aquarium. The magnet will have a piece of Velcro attached to it. You will be given a plastic film container, a piece of Velcro that will 'hook' onto the piece of Velcro on the magnet, and one Alka-Seltzer tablet. You may cut, drill or modify the container any way you want however, your teacher will be the final judge as to whether your plan is appropriate.

**Your Limitations:**

The submarine must descend and ascend without being touched or guided by anything attached to it. After you place it—you cannot drop it—on the water surface, you cannot touch it. Your sub must descend and come back to the surface using only the principles of physics and sinking and floating.

You will have 2 chances to retrieve the magnet. You will not be given any additional Velcro, Alka-Seltzer or film containers, but you are free to use any of your own resources and you are urged to test the design until you are satisfied it will work.

**Your Reward:**

Watching your partner work = 0 points
Active participation =10 points
Successful completion = 10 BONUS points

**Before the Final Trials:**

Submit a detailed plan of the submarine and a detailed description of what you think will happen. Be sure to include a detailed explanation of WHY your design will work. On the back of this page, draw a picture of your submarine and label the parts. Write your explanation below and use extra sheets if needed. **Be specific! Explain your reasoning! One or two sentences will not be sufficient.**

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________________________________________________________________________________
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# APPENDIX J

MINI-SUB INSTRUCTIONS PAGE 2

Mini-Sub Activity page 2

*PROVEiT!*

Topic: Heat And Temperature Date:__________ Coded ID: __________

--------------------------------------------------------cut here--------------------------------------------------------------

Now classify the parts of your explanation (1 point for each valid entry):

Claim (1 pt. use only one):______________________________________________________________

______________________________________________________________________________

Changes (to be used by your opponent) ____________________________________________

______________________________________________________________________________

Data (1 pt. ea. you can use more than one):_______________________________________________

______________________________________________________________________________

Changes (to be used by your opponent) ____________________________________________

______________________________________________________________________________

______________________________________________________________________________

Warrant (1 pt. ea. you can use more than one):

______________________________________________________________________________

______________________________________________________________________________

Changes (to be used by your opponent) ____________________________________________

______________________________________________________________________________

______________________________________________________________________________

Qualifier (1pt. ea. you can use more than one):_____________________________________________

______________________________________________________________________________

______________________________________________________________________________

Changes (to be used by your opponent) ____________________________________________

______________________________________________________________________________

______________________________________________________________________________

# APPENDIX K

MINI-SUB INSTRUCTIONS PAGE 3

# Mini-Sub Activity page 3

Backing (1 pt. ea. you can use more than one):______________________________________

____________________________________________________________________________

____________________________________________________________________________

Changes (to be used by your opponent) ______________________________________

____________________________________________________________________________

____________________________________________________________________________

Rebuttal (2 points ea.-you can use more than ______________________________________

____________________________________________________________________________

____________________________________________________________________________

____________________________________________________________________________

Changes (to be used by your opponent) ______________________________________

____________________________________________________________________________

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# APPENDIX L

CARTESIAN DIVER PAGE 1

*PROVEiT!*

Names_______________________________________________

-----------------------------------------------------------cut here-------------------------------------------------------

*PROVEiT!*

Topic: Cartesian Diver  Date:________________  Coded ID: ________________

In class, you made a Cartesian diver. For this activity, you need to make your argument about why the diver descends or ascends in the bottle when you press and release the sides of the bottle. Keep in mind that the diver does not sink until something happens. You should write your argument using at least two of the concepts we covered in class.

PART 1:

Why it worked (One paragraph maximum):_______________________________________________

_______________________________________________

_______________________________________________

_______________________________________________

_______________________________________________

_______________________________________________

_______________________________________________

_______________________________________________

Now classify the parts of your explanation (1 point for each valid entry):

Claim (1 pt. use only one):_______________________________________________

_______________________________________________

Changes (to be used by your opponent) ________________________________

_______________________________________________

Data (1 pt. ea. you can use more than one):________________________________

_______________________________________________

Changes (to be used by your opponent) ________________________________

_______________________________________________

_______________________________________________

# APPENDIX M

CARTESIAN DIVER PAGE 2

Cartesian Diver page 2

Warrant (1 pt. ea. you can use more than one): ____________________________________________

____________________________________________________________________________________

____________________________________________________________________________________

Changes (to be used by your opponent) ____________________________________________

____________________________________________________________________________________

____________________________________________________________________________________

Qualifier (1pt. ea. you can use more than one):____________________________________________

____________________________________________________________________________________

____________________________________________________________________________________

Changes (to be used by your opponent) ____________________________________________

____________________________________________________________________________________

____________________________________________________________________________________

Backing (1 pt. ea. you can use more than one):____________________________________________

____________________________________________________________________________________

____________________________________________________________________________________

Changes (to be used by your opponent) ____________________________________________

____________________________________________________________________________________

____________________________________________________________________________________

Rebuttal (2 points ea.-you can use more than ____________________________________________

____________________________________________________________________________________

____________________________________________________________________________________

____________________________________________________________________________________

Changes (to be used by your opponent) ____________________________________________

____________________________________________________________________________________

____________________________________________________________________________________

# APPENDIX N

BUOYANCY INTERVIEW

Buoyancy Interview

Student Name________________________

1. When I push on the sides of the bottle, the diver descends. Why? ___________________

_____________________________________________________________________________

_____________________________________________________________________________

2. What determines if something sinks in a fluid?___________________________________

_____________________________________________________________________________

____________________________________________________________________________

3. What is happening in the diver to make it sink? __________________________________

_____________________________________________________________________________

_____________________________________________________________________________

4. One student claims that when the sides of the bottle are pressed, the pressure increases at the top of the bottle and forces the diver to go down. Another student says that the pressure makes the water weigh more and that forces the diver to sink. Which if either is correct?

_____________________________________________________________________________

_____________________________________________________________________________

_____________________________________________________________________________

# APPENDIX O

## BUOYANCY FORMATIVE ASSESSMENT

Buoyancy Formative Assessment Name____________________________________

1. Susan and Jake spent the afternoon anchored in a boat while they were fishing. When it came time to go home, they hoisted the anchor. Jake easily pulled the anchor up until it came out of the water. When it came out of the water it suddenly felt much heavier and Jake needed Susan's help to lift it into the boat. Why?

________________________________________________________________________________

________________________________________________________________________________

________________________________________________________________________________

________________________________________________________________________________

2. When they returned home, Jake decided he wanted a hard-boiled egg. He filled a pan to the rim with water, placed the pan on the stove and put the egg gently on the surface and released it. Water spilled over the edge of the pan onto the stove. Why?

________________________________________________________________________________

________________________________________________________________________________

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# APPENDIX P

## HEAT INTERVIEW

Heat Interview

Student________________________________

1. What is heat?

________________________________________________________________________________

________________________________________________________________________________

________________________________________________________________________________

2. How is heat different from temperature?

________________________________________________________________________________

________________________________________________________________________________

________________________________________________________________________________

3. What does a refrigerator do so that water can freeze?

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________________________________________________________________________________

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# APPENDIX Q

HEAT FORMATIVE ASSESMENT

Heat Formative Assessment

THE MITTEN PROBLEM Name______________________________

Sarah's science class is investigating heat energy. They wonder what would happen to the temperature reading on a thermometer if they put the thermometer inside a mitten. Sara's group obtained two thermometers and a mitten. They put one thermometer inside the mitten and the other thermometer on the table next to the mitten. An hour later they compared the reading on the two thermometers. The temperature inside the room remained the same during their experiment. What do you think Sarah's group will discover from their investigation? Circle the response that best matches your thinking.

A. The thermometer inside the mitten will have a lower temperature reading than the thermometer on the table.
B. The thermometer inside the mitten will have a higher temperature reading than the thermometer on the table.
C. Both thermometers will have the same temperature reading.

Describe your thinking. Provide an explanation for you answer.

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Adapted from: Keeley, P., Eberle, F., & Dorsey, C. (2005). Uncovering student ideas in science, vol. 1: 25 formative assessment probes. Arlington: NSTA Press.

# APPENDIX R

## HEAT AND TEMPERATURE ACTIVITY PAGE 1

Heat and Temperature Activity page 1

*PROVEiT!* Names_______________________________________

------------------------------------------------------------cut here----------------------------------------------------------

*PROVEiT!*

Topic: Heat And Temperature Date:_________ Coded ID: _________

DO NOT TOUCH THE METAL OR THE WOOD UNTIL YOU ARE DIRECTED.

On the table you have two objects. Both have been sitting on the table for a long time. Before you do anything, estimate what the temperature of each will be.

_____________Ask the teacher to find the temperature of the room. Record it here.

Estimate of the temperature of the objects on the table.

____________ Temperature of the metal

____________ Temperature of the wood

Now feel the metal and then feel the wood. What do you notice? Record your observations.

______________________________________________________________________________

______________________________________________________________________________

Put the thermometer in the hole in the object and wait for the temperature to stabilize.

_____________Record the temperature of the metal.
_____________Record the temperature of the wood.
_____________Did the temperature of each match your estimate?

How can you explain the difference in the temperature differences (if any) you experienced? Write your argument here.

______________________________________________________________________________

______________________________________________________________________________

______________________________________________________________________________

______________________________________________________________________________

______________________________________________________________________________

# APPENDIX S

HEAT AND TEMPERATURE ACTIVITY PAGE 2

# Heat and Temperature Activity page 2

*PROVEiT!*

Topic: Heat And Temperature Date:__________ Coded ID: __________

Now classify the parts of your explanation (1 point for each valid entry):

Claim (1 pt. use only one):____________________________________________________________

________________________________________________________________________________

Changes (to be used by your opponent) ____________________________________________

________________________________________________________________________________

Data (1 pt. ea. you can use more than one):_______________________________________________

________________________________________________________________________________

Changes (to be used by your opponent) ____________________________________________

________________________________________________________________________________

________________________________________________________________________________

Warrant (1 pt. ea. you can use more than one): ____________________________________________

________________________________________________________________________________

________________________________________________________________________________

Changes (to be used by your opponent) ____________________________________________

________________________________________________________________________________

________________________________________________________________________________

Qualifier (1pt. ea. you can use more than one):___________________________________________

________________________________________________________________________________

________________________________________________________________________________

Changes (to be used by your opponent)

________________________________________________________________________________

________________________________________________________________________________

APPENDIX T

HEAT AND TEMPERATURE ACTIVITY PAGE3

# Heat and Temperature Activity page 3

Backing (1 pt. ea. you can use more than one):____________________________________

______________________________________________________________________

______________________________________________________________________

Changes (to be used by your opponent) ____________________________________

______________________________________________________________________

______________________________________________________________________

Rebuttal (2 points ea.-you can use more than ____________________________________

______________________________________________________________________

______________________________________________________________________

______________________________________________________________________

Changes (to be used by your opponent) ____________________________________

______________________________________________________________________

______________________________________________________________________

# APPENDIX U

THERMODYNAMICS INTERVIEW

Thermodynamics Interview

Name ________________________________

1. Why do pots and pans have plastic handles?

___________________________________________________________________________

___________________________________________________________________________

___________________________________________________________________________

2. You stand in front of a bonfire on a cold night. Why does your face feel warm, but your back feels cold?

___________________________________________________________________________

___________________________________________________________________________

___________________________________________________________________________

3. Some people will put an ice cube in a cup of hot coffee to cool it. What is happening so that the coffee cools?

___________________________________________________________________________

___________________________________________________________________________

___________________________________________________________________________

# APPENDIX V

## THERMODYNAMICS FORMATIVE ASSESSMENT

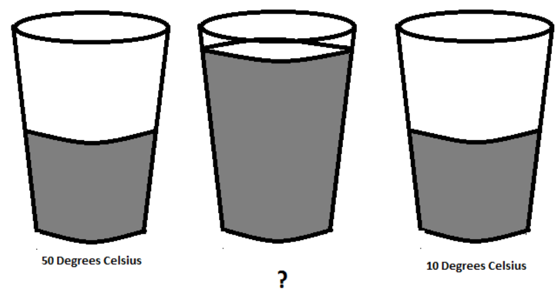
# Thermodynamics Formative Assessment

## MIXING WATER

Melinda filled two glasses of equal size half-full with water. The water in one glass was 50 degrees Celsius. The water in the other glass was 10 degrees Celsius. She poured one glass into the other, stirred the liquid, and measured the temperature of the full glass of water.

What do you think the temperature of the full glass of water will be after the water is mixed? Circle your prediction.

A. 20 Degrees Celsius
B. 30 Degrees Celsius
C. 40 Degrees Celsius
D. 50 Degrees Celsius
E. 60 Degrees Celsius




Explain your thinking. Describe the "rule" or reasoning you used for your answer.

______________________________________________________________________________

______________________________________________________________________________

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______________________________________________________________________________

Adapted from: Keeley, P., Eberle, F., & Dorsey, C. (2007). Uncovering student ideas in science, vol. 2: 25 more formative assessment probes. Arlington: NSTA Press.

# APPENDIX W

THERMODYNAMICS ACTIVITY PAGE 1

# Thermodynamics Activity page 1

*PROVEiT!* Name______________________________________________

Critique writer name___________________________________

------------------------------------------------------------cut here------------------------------------------------------------

*PROVEiT!*

Topic: Thermodynamics Activity Date:_____________ Coded ID: ___________________

Critique Writer Coded ID: ___________

Terry Bull and Barb Dwyer are students at Le Burnt Toast cooking school. They were given an assignment of selecting pots and pans to use in their classes. Terry claimed that pans with copper bottoms would be best because they would heat up fast and reduce cooking time. Barb wanted Aluminum pans because she says they will heat up faster than the copper and retain more heat before they get hot and that means they will heat food more evenly. They tested their ideas with a special stove that added 20,000J of heat energy to each pan. Each pan weighs 500 g. Which person, if either, has made a better claim? Your job is to decide if either person has made a reasonable argument, and to improve what they claim.

| **Substance** | **C in J/gm K** |
|---|---|
| Aluminum | 0.900 |
| Copper | 0.386 |
| Water | 4.186 |
| Glass | 0.84 |
| Iron | 0.449 |

$Q = m*c*\Delta t$

Write your argument here: ________________________________________________________

______________________________________________________________________________

______________________________________________________________________________

______________________________________________________________________________

______________________________________________________________________________

______________________________________________________________________________

______________________________________________________________________________

Now classify the parts of your explanation (1 point for each valid entry):

Claim (1 pt. use only one):__________________________________________________

______________________________________________________________________________

Changes (to be used by your opponent) ____________________________________

______________________________________________________________________________

# APPENDIX X

THERMODYNAMICS ACTIVITY PAGE 2

# Thermodynamics Activity page 2

Data (1 pt. ea. you can use more than one):_______________________________________________

_____________________________________________________________________________

Changes (to be used by your opponent) ____________________________________________

_____________________________________________________________________________

_____________________________________________________________________________

Warrant (1 pt. ea. you can use more than one): _____________________________________________

_____________________________________________________________________________

Changes (to be used by your opponent) ____________________________________________

_____________________________________________________________________________

_____________________________________________________________________________

Qualifier (1pt. ea. you can use more than one):_____________________________________________

_____________________________________________________________________________

Changes (to be used by your opponent) ____________________________________________

_____________________________________________________________________________

_____________________________________________________________________________

Backing (1 pt. ea. you can use more than one):_____________________________________________

_____________________________________________________________________________

Changes (to be used by your opponent) ____________________________________________

_____________________________________________________________________________

_____________________________________________________________________________

Rebuttal (2 points ea.-you can use more than one)__________________________________________

_____________________________________________________________________________

_____________________________________________________________________________

Changes (to be used by your opponent)____________________________________________

_____________________________________________________________________________

# APPENDIX Y

## SCORING SHEET

Scoring Sheet

*PROVEiT!* Names__________________________________________

-------------------------------------------------------cut here-------------------------------------------------------

*PROVEiT!*

Topic: Thermodynamics Activity Date:________ Coded ID: _______________

## SCORING SHEET

Now, give your explanations to the person you are playing against. Read their explanation, and classifications. The object of the game is to improve what they wrote. If you can make a better claim, qualifier etc. you get their points for that item.

**SCORING—** add up the points you earned after your opponents critique and enter them in section 1. Add up the points you earned from improving your opponents argument and enter them in section 2. If your opponent disproved any of your items, those need to be subtracted, so enter the points to be subtracted in section 3. Complete section 4 to determine your final score. The person with the highest score wins a brand new Cadillac, a blu-ray DVD player and $1000.00 cash! (the principal will gladly give you the money for this, so be sure to get ALL the available options).

1. Points I earned from my argument:

Claim: ___________
Data: ___________
Warrant: ___________
Qualifier: ___________
Backing: ___________
Rebuttal: ___________

**Total:** ___________

2. Points I earned by improving my opponents argument:

Claim: ___________
Data: ___________
Warrant: ___________
Qualifier: ___________
Backing: ___________
Rebuttal: ___________

**Total:** ___________

**3. Total points from section 1 & 2** ___________

Points I lost because of my opponent's critique:

Claim: ___________
Data: ___________
Warrant: ___________
Qualifier: ___________
Backing: ___________
Rebuttal: ___________

**4. Total:** ___________

Total Score: subtract Line 4 from Line 3 **ENDING SCORE** ___________

# APPENDIX X

ARGUMENTATION SURVEY

Argumentation Survey Name______________________

| | Strongly Agree | Agree | Neutral | Disagree | Strongly Disagree |
|---|---|---|---|---|---|
| 1. I feel like I can write a good argument now | 5 | 4 | 3 | 2 | 1 |
| 2. We needed more practice in writing arguments | 5 | 4 | 3 | 2 | 1 |
| 3. I don't see the need for knowing how to argue like we have been doing it. | 5 | 4 | 3 | 2 | 1 |
| 4. I am confused about the meaning of some of the terms, like warrant, qualifier, etc. | 5 | 4 | 3 | 2 | 1 |
| 5. I liked the idea of keeping score. | 5 | 4 | 3 | 2 | 1 |
| 6. Keeping score helped me improve my arguments. | 5 | 4 | 3 | 2 | 1 |
| 7. Writing an argument helped me understand the material we were studying. | 5 | 4 | 3 | 2 | 1 |
| 8. Reading a critique of my argument helped me write better arguments. | 5 | 4 | 3 | 2 | 1 |
| 9. Critiquing someone's arguments helped me improve my arguments. | 5 | 4 | 3 | 2 | 1 |

10. The thing that helped me understand how to write arguments was:_____________________________________________
_________________________________________________________________

11. The most confusing part of writing arguments was: ___________________________________________________
_________________________________________________________________

12. The hardest part of writing arguments was: ________________________________________________________
_________________________________________________________________

13. A helpful change/change would be: ___________________________________
_________________________________________________________________

APPENDIX AA

POST INTERVENTION INTERVIEW

Post Intervention Interview Name_______________________________________

1. How did critiquing other arguments help or hinder your own arguments?

______________________________________________________________________________

______________________________________________________________________________

2. How did the critiques of your arguments by others help or hinder you?

______________________________________________________________________________

______________________________________________________________________________

3. How did the knowledge that your arguments would be looked at by classmates affect how you wrote your argument?

______________________________________________________________________________

______________________________________________________________________________

4. Overall, was this method of learning how to write an argument helpful?

______________________________________________________________________________

______________________________________________________________________________

5. How could it be improved?

______________________________________________________________________________

______________________________________________________________________________