

THE IMPACT OF ARGUMENT DRIVEN INQUIRY ON STUDENT
UNDERSTANDING OF CONCEPTS BEING REINFORCED
DURING SCIENCE LABORATORY ACTIVITIES

by

Tracey Ann Bidwell

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ABSTRACT

This action based research project focused on Argument Driven Inquiry as a means to improve student learning during science laboratory investigations. The goal of the research was to determine if using argumentation, as part of the laboratory experience, would help students use their data to explain what was happening in the investigation. After students presented an oral argument in class and listened to other arguments, each individual wrote a conclusion to the laboratory investigation. The objective was to use argumentation as a means to help students gain a better understanding of the concepts covered by the laboratory investigation.

INTRODUCTION AND BACKGROUND

This research paper looked at how to improve the students' ability to gain information from laboratory investigations. The action research focused on increasing students' knowledge of key concepts covered in hands-on activities by using Argument Driven Inquiry. The goal was to help students write meaningful conclusions to their lab write-ups that showed an understanding of the key concepts taught during the lab. This action research investigated the following question: Would Argument Driven Inquiry improve the quality of conclusions written in the lab write-ups and would the approach help the students gain a greater understanding of the concepts being taught? The students were asked to comment on how the Argument Driven Inquiry helped them and how they felt about the process.

I teach at Venture Academy, a public charter school, in Stockton, California. Venture Academy is a kindergarten through high school program that also participates in a cohort with Grand Canyon University. Students can start with us in kindergarten, earn a high school diploma, and complete 32 college credits (Venture Academy Family of Schools, 2015). Many students and parents choose to attend Venture Academy to avoid large school districts with over crowded unsafe environments. The school also has a home school component where parents can receive assignments and learning goals, work with their children at home, and then meet with a staff member to assess student progress. My primary research question was: Would the use of argumentation in Argument Driven Inquiry improve the students' understanding of the concepts being covered in a laboratory investigation? The secondary research questions that I looked at were: What

was student perception of argumentation? Can the argumentation process be used with multiple formats of laboratory activities, inquiry activities, misconception probes, and discrepant events? Would the argumentation process better prepare students for the rigors of common core?

CONCEPTUAL FRAMEWORK

The first part of the research, which shaped the initial focus for the research question, was in the area of inquiry. Inquiry is an active process for the students and requires them to engage in the activity (Anderson, 2002). This process shifts the roles of both students and teacher. The teacher's role becomes that of a facilitator, while the students' roles become that of investigators and discoverers. The process moves the students from a passive learners' role into an active learners' role where they take responsibility for their learning.

The research showed that there were three main areas to address, or to be aware of, in inquiry activities. Van Rens, Pilot, & van der Schee, 2009, classified these as willingness, ability, and knowing. In the area of willingness students must be willing to participate. If the inquiry is interesting to the student they are more likely to participate. The activity needs to be structured at a level that the students can achieve, and there must be appropriate guidance from the teacher. The activity needs to be carefully selected so that it fits the students' ability level. This includes formulating questions, use of equipment, knowledge of variables, and the ability to carry out the investigation (van Rens, Pilot, & van der Schee, 2009). In the area of knowing students need to have a general understanding of inquiry. This is the part where students will need to be guided

by the instructor. It is also the part of the activity where they tie knowledge of the investigation to the concepts being taught.

Rebecca Dobson's Capstone Research Project was also looking for a means to improve student knowledge gained from laboratory investigations. The focus of her project was to look at how direct instruction, in the area of written scientific explanations, would impact student performance on extended response questions (Dobson, 2014). While the study showed only some positive results in improving the scientific explanation process it was centered on the writing process. The focus on written scientific explanations did not provide a clear tie between concepts being covered in the laboratory investigations and the written conclusions.

This research project had the same goal but looked at a different means to arrive at the end results. This research project looked to improve the laboratory investigation process, and the ties to the evidence that the students collected. An emphasis was placed on how the information was reported in their lab conclusions, by using an argumentation process to help the students tie what they learned during the investigation to the concepts taught.

During the research on improving laboratory investigations, I came across references to Argument Driven Inquiry (ADI). In this process the students were given a task, or a challenge problem, to investigate. The next step was for students to work together in teams to generate data and analyze it. These initial steps followed the inquiry process. The third step is where ADI differs. In the third step students used the data that they obtained to produce an argument to support their analysis of the data. In the fourth

step students had an opportunity to share their argument with the class and to evaluate the arguments of other groups. The fifth and final step of the process was to take the oral argument and turn it into a written argument (Walker & Sampson, 2011).

This process was similar to a performance assessment where a student had to perform or demonstrate a task while they were observed and assessed. In my experience, the students put forth more effort when the results were watched and assessed. The oral argument portion of the ADI would place the students in the position similar to a performance assessment. Students would present, as well as listen to oral arguments to obtain the necessary evidence to improve their understanding of the investigation. With increased understanding, the students have the confidence and knowledge to improve their written arguments (Walker & Sampson, 2011).

Scientists take their evidence and engage in argumentation of the evidence with other scientists to develop a stronger explanation of what they have found. In education this same concept could be applied to improving laboratory investigation in the classroom. It is possible that students who engage in argumentation could also develop better explanations. The process of argumentation based on the evidence collected during a laboratory activity may help the students develop a better explanation, similar to the practices of scientists (Berland & McNeil, 2012).

In their 2005 study, Kuhn and Reiser found that when students have an opportunity to communicate their understanding to their peers they were able to assess the strengths and weaknesses of their understanding. The process of arguing their findings allowed the students to receive feedback from their peers and modify their ideas.

The process strengthened student understanding of the concepts and allowed them to make changes where they were confronted with errors. One key area that students needed to be aware of was the difference between inference and evidence. As students gained a clear understanding of these two areas they would be able to use more evidence to argue their points and strengthen their arguments. One area of concern was the connection between the oral discussion in the laboratory group and the final written report. The students were not always able to take the clear oral discussion and place it into a clear written explanation (Kuhn, & Reiser, 2005).

Several types of laboratory activities support the Argument Driven Approach. One of these is the “Mini-Lab”. The Mini-lab was described in Branan and Morgan’s 2010 study. It started with a chemical phenomenon and students made observations based on it. The Mini-Lab process led the students through a series of increasingly deeper questions about the observations ending in a final question. It was set up to be collaborative and to facilitate a discussion among the students to help them arrive at a deeper understanding of the concept. After the class discussion, students were given five minutes to answer one final question regarding the topic. The goal was to get students to think about how and why something happened (Branan, & Morgan, 2010).

Teaching the Molecular Diffusion Lab had a similar format to that of the Mini-Labs. In this lab, students had a basic setup that they were given. They made predictions about what would happen before the reactants were added to the apparatus. Once the reactants were added, the students collected observational data. A discussion followed, and students determined if their predictions were correct based on their observations.

The students worked together to determine what was happening with the reaction and why. The key component in the Molecular Diffusion laboratory was students working together to arrive at an evidence-based explanation for what was happening during the investigation (van Rens, & van der Schee, 2009).

Criswell (2012) presented another investigation which asked students to tap into their knowledge of beauty. This investigation asked them to use the principles of Valence Shell Electron Pair Repulsion theory to determine if one molecule was more attractive than another. The students were asked to group molecules into symmetrical and asymmetrical groups and discuss why they placed the molecules into these groups. A discussion allowed the opportunity for students to tie the appearance of the molecules to what they had learned about molecular geometry (Criswell, 2012). Each of these investigations provided the opportunity for the students to engage in a small group discussion culminating into a whole class argumentation.

The review of the literature showed the use of argumentation in the laboratory process to be a key concept to improve student understanding. The evidence of the use of oral argumentation, after the students completed an investigation to explain their evidence and discuss their findings, benefited all involved. The argumentation process gave the laboratory investigation a performance assessment component. The literature review showed several different formats for laboratory investigations that used the argumentation process. These formats provided a wide variety of methods to explore during the research project.

METHODOLOGY

The investigation focused on how the use of argumentation would expand the knowledge of the students, and helped to make them more accountable for their own learning. The research project used the literature review to develop laboratory activities that would give a clear question, and a means for the students to develop an oral argument. The laboratory investigations selected allowed for the oral arguments that could easily be presented to the class. These activities helped students use the information gained to write a conclusion explaining the concepts taught in the laboratory activity.

I used my two sections of chemistry for my action research. I worked with a total of 59 students in these two sections which involved my second and third periods. My second period chemistry class had 27 students, 14 of which were girls and 13 were boys. My third period chemistry class had 32 students, 22 of which were girls and 10 were boys (Venture Academy Family of Schools, 2015).

The first part of the research established a baseline for comparing details covered in laboratory conclusions and concept understanding. A comparison was made between the typical laboratory investigation and the investigations completed using argument driven inquiry. I used the same rubric (Appendix A) to assess all conclusions for both types of investigations. The rubric excluded the oral component for the initial laboratory activities that did not use the argumentation process. The baseline allowed me to compare and contrast the amount of information students were obtaining from laboratory investigations both pre and post argument driven inquiry. I also used some pre-tests and post-tests to determine students' understanding of the concepts.

Next, I looked at several types of investigations that were used to facilitate the argumentation process. Lab investigations selected to meet the concepts covered at the time the project was carried out included discrepant events, misconception probes, and multiple inquiry activities. The first activity used was a Balancing Equations Argumentation activity (Appendix C). The students were given a word equation on the Claims and Evidence Form and asked to convert it to the chemical formulas and balance the equation. This activity introduced the argumentation process. As a group, the students wrote a correct balanced equation. The students then used evidence and justifications for how they got the correct equation. This was a good activity to start the argumentation process because it did not require a complicated lab procedure and students could focus completely on the argumentation process.

The next lab activity was the Decomposition of Water Lab (Appendix D). This inquiry activity had students use a hand generator, pencil lead, and salt to separate water into hydrogen and oxygen. Students were given the Claims and Evidence Form to collect evidence during the lab. After the lab, students justified the evidence that they collected and developed an argument. This was a simple lab to complete with multiple complex chemistry topics to explain. The only background information the students were given was on the lab worksheet and the information sheets that came with the hand generator. Students had to find the remaining information on their own using their textbooks and internet sources.

I also used the Golf Ball Ping Pong Ball Discrepant Event for one of the argumentations (Appendix E). In addition to the discrepant event, I also used the Rusty

Nail Misconception Probe (Appendix F). Students completed a misconception probe worksheet. After the worksheet was completed, the students filled out the Claims and Evidence worksheet (Appendix B) working in a lab table group. After the Claims and Evidence worksheet was completed, the students conducted an oral argumentation process. Each group gave their argumentation stating which answer they felt was correct. Once each of the groups had given their arguments, each of the students wrote their written argument final statement based on their observations and justifications. The written and oral arguments were scored using the rubric (Appendix A). Both of these activities gave the students the opportunity to look at areas where they could have wrong answers. If they could not justify the answer, then they had the opportunity to give an answer they could justify. The activities also required the students to collect evidence and justify that evidence rather than give explanations based on what they thought.

I also used the Mole Lab for the argumentation process (Appendix G). The Calculating Moles Lab, (Appendix H), was used but the argumentation process was not done for this lab. The students were asked to complete the lab and write a conclusion without the argumentation. The last activity was the Gas Laws Lab (Appendix I). This activity was the final argumentation activity used for the research.

All lab activities included an oral argument component to help students learn to utilize their data and gain an understanding of the concepts being taught. After the students performed the investigations and argumentation, their lab write-ups were assessed using the rubric provided (Appendix A). The conclusions were worth twenty points for full credit and an additional five points for areas that went above and beyond

the expectations, true works of wonder. Laboratory conclusions were compared and contrasted throughout the process. Surveys were given to assess students' opinions regarding the use of argumentation as part of the laboratory process.

Student surveys included open-ended questions to determine each student's perspective of the argumentation process, and if it helped to facilitate a greater understanding of the concepts being taught. The final written arguments were compared to the baseline laboratory conclusions written before the argumentation process using the rubric established in (Appendix A). Conclusions were assessed to determine if more concepts were present after the argumentation process.

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 (Appendix M). The data was collected following the Triangulation Matrix.

Table 1
Triangulation Matrix

Focus Question: Will the use of argumentation in Argument Driven Inquiry improve the students' understanding of the concepts being covered in a laboratory investigation?			
Subquestions	Data Source		
Subquestion 1: What is the student perception of laboratory conclusions?	Chemistry Attitudinal Surveys December	Chemistry Attitudinal Surveys May	Classroom Discussions
Subquestion 2: Do multiple formats of argumentation, inquiry activities, misconception probes, and discrepant events increase or improve the argumentation process?	Pre-argumentation Survey	Post-Argumentation Survey	Analysis of lab conclusions from pre-treatment and post-treatment.
Subquestion 3: Will the argumentation process better prepare students for the rigors of common core?	Baseline data from pretreatment labs using the rubric for assessment.	Improvement on Completion of Claims / Evidence worksheet over time.	Improvement in the ability to use data in argumentation.

DATA AND ANALYSIS

The data collection began by comparing the differences between the lab conclusions both with and without the argumentation process. Next, I included the data from the Chemistry Attitudinal Surveys, both Pre-Argumentation and Post-Argumentation. The last part of the data analyzed was the data from the Pre-Argumentation Survey and the Post-Argumentation Survey.

Argumentation Data

The argumentation data helped me answer the primary research question: Will the use of argumentation in Argument Driven Inquiry improve students' understanding of the

concepts being covered? The argumentation data also showed the effectiveness of multiple lab and inquiry formats used throughout the research process.

Figure 1 shows a conclusion before the argumentation process. This conclusion was typical of most of the students' conclusions before the argumentation process. The student explained what happened in the lab by stating what was observed. However, the explanation lacks the use of academic vocabulary related to the lab itself. The student missed the key concepts of an emission spectra and what it tells about the element. Very little evidence or justification of the data was used in the conclusion.

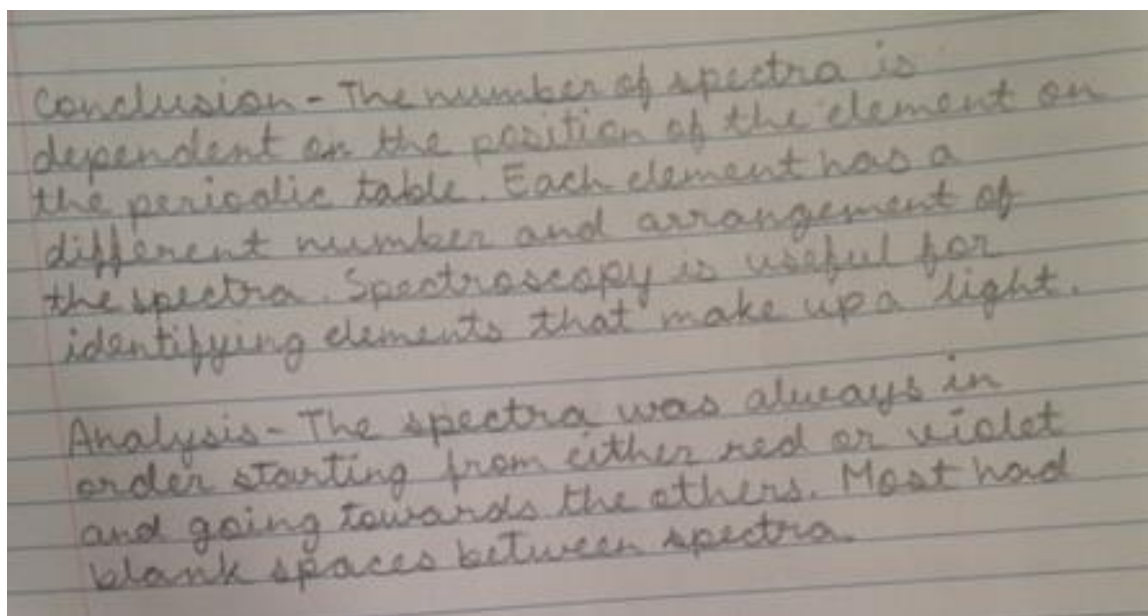


Figure 1. Picture of a lab conclusion before the argumentation process.

The first argumentation, Balanced Equation Argumentation (Appendix C), had a wide range of focus areas for the different groups. Student groups were assigned numbers to distinguish one group's argument from another's. The groups were not the same for all argumentations. With the first group the argumentation had basic evidence, but the group did not have much in the justification area shown in Figure 2. What was most interesting

was the fact that this group mentions the need for a stable octet as a reason for bonding to occur. There was also evidence of the students working through the steps and explanations of what they did to balance the equation, which was summarized in the final statement.

Our Evidence: we know that Ba has a 2^+ charge and Cl has a negative charge $BaCl_2$ K has 1^+ charge and S & O has a negative charge K_2SO_4 There's 2 potassium and 2 chlorides so to balance it out you need the same amount	Our Justification of the Evidence: • All compounds must have a charge of 0. • We need the same amount of molecules & atoms on each side.
Final statement or rule: Atoms react in order to gain a stable octet. All compounds must have a charge of zero. so when Cl^+ with potassium they both are - so you put the two to balance them out.	

Don't produce side. To balance it out we need four oxygens as well so its $BaSO_4$.

Figure 2. Picture of Claims and Evidence Argumentation for Balanced Equation Group 1.

Group 2 showed very little evidence and justification in Figure 3. However, what was most clear was the students' ability to listen to the other groups and incorporate the other arguments into the final statement. The final statement included the law of conservation of matter as well as vocabulary, such as electrically neutral. In the group's

statement they explained what was happening with equal numbers of atoms on both sides. However, in the final statement, written in black, the student actually named it as the law of conservation of mass. The same was true with the statement, written in blue, about being electrically neutral. The evidence was in the first statement, but again the final statement was more sophisticated using electrically neutral.

Our Evidence: K^+Cl^- $Ba^{2+}Cl_2^{2-}$ $2KCl$	Our Justification of the Evidence: All compounds must have a charge of ϕ. So we have 2 potassium and 2 chloride on both sides.
Final statement or rule: To balance an equation you need the same number of atoms of an element on both side and a charge of ϕ	
Final statement: The law of conservation of mass applies to chemical reactions. Compounds will form to make electrically neutral compounds. to balance an equation you need the same number of atoms of an element on both side and a charge of ϕ.	

Figure 3. Picture of Claims and Evidence Argumentation for Balanced Equation Group 2.

Group 3 had more in the evidence and justification column in Figure 4. The explanations and the steps were a little more sophisticated for this group. However, the final statement found on the back of the worksheet had incorporated many details and

vocabulary in Figure 5. In the statement the student stated the type of reaction as well as the rules for balancing charges. The student stated that there were reactants and products. The use of coefficients to balance atoms on both sides was also explained.

Our Evidence: - Only the potassium and chloride atoms were unbalanced - there were 2 potassium and 2 chlorine atoms on the reactant side - <u>2</u> KCl	Our Justification of the Evidence: - to balance the equation we need to balance all the atoms - we need the potassium and chlorine atoms on the product side to have the same amount of atoms - we need to keep the reactant side and product side balanced
Final statement or rule: The potassium and Chlorine are unbalanced so we put the coefficient in front of them on the product side to balance the equation.	

Figure 4. Picture of Claims and Evidence Argumentation for Balanced Equation Group 3.

The chemical equation is a double replacement and needs to be balanced. All of the compounds on the reactant and product sides need to have an overall charge of zero and need to have the same amount of atoms on both sides. Potassium and Chlorine both need 2 atoms to remain balanced so we put a coefficient of 2 in front of KCl.

Figure 5. Picture of the Final Statement located on back of Group 3 argumentation.

The next argumentation used was the Decomposition of Water Lab. This was an inquiry activity that exposed the students to new terms that they had not been taught.

Cathode, anode and electrolysis had not been discussed in class and left the students to formulate their own understanding of these terms during the lab. In this argumentation, students had a dramatic improvement using the evidence and justification section. In Figure 6, the student used the evidence and justification section to list definitions and explanations for the lab. While this is not exactly what I had in mind for the evidence and justifications, it was clear that a considerable amount of academic vocabulary was being defined and then used in the final statement. The students were moving outside the constraints of the boxes and using the worksheet to collect all of the relevant information in a format that worked for them.

Question / Purpose: What is the chemistry between the decomposition of water?	
Our Claim: The electrical current is passed through water between the positive and negative, the water is split into two parts which is oxygen and hydrogen. This process is called electrolysis. $2\text{H}_2 + \text{O}_2 \rightarrow 2\text{H}_2\text{O}$	
Our Evidence: +S - Electrolysis - the decomposition of water into oxygen & hydrogen gas due to an electric current being passed through the water. +S +S +S +S - Thermolysis - chemical reaction where by a chemical substance breaks up into at least two chemical substances when heated.	Our Justification of the Evidence: Hydrolysis - reactions that use water to break down polymers into monomers & is the opposite of dehydration synthesis, which forms water when synthesizing a polymer from monomers. - Anode - where negative ions are generated - Cathode - where positive ions are generated
Final statement or rule: The chemistry between the decomposition of water is the electrical current that passed through water between positive and negative, it splits into two parts which is oxygen and hydrogen. This is called electrolysis. The products in this process are two volumes of hydrogen at the cathode and one volume of oxygen at the anode.	

Figure 6. Picture of Argumentation for the Decomposition of Water Group 1.

Several groups went to a list format of evidence and justifications and needed the backside of the worksheet or additional paper in Figure 7 and 8. One group had an extensive list for the evidence and justifications. Some of the justifications were incorrect. For example, lead was a metal, but the lead that was used was pencil lead, which is carbon. There was a solid justification of how the group determined the difference between an anode and cathode. In addition, this argumentation showed a drawing, which was present on many of the students' argumentations. The

argumentations from this lab showed multiple concepts and academic terms used by all groups. The oral argumentations presented were sophisticated, incorporating terminology that students learned on their own.

Hydrogen already has 2 atoms so it bubbles faster than oxygen, oxygen has to bond with another oxygen atom

Question / Purpose: what are the different chemical concepts being used in the decomposition of water.

Our Claim: The electrolysis breaks the bonds between hydrogen & oxygen in H_2O . The water is being broken down into H_2 & O_2 (gases). The led & salt are the conductors. The bubbles rise faster on the negative electrolyte because the gas that is broken down fastest is H^+ which is $+$, causing the hydrogen bubbles to be attracted to the negatively charged led.

Our Evidence:

- Spinning the handle creates electricity which causes water to bubble around lead
- The direction handle is spun indicates which piece of led is negatively charged
- Bubbles are rising

Our Justification of the Evidence:

- which shows us that the negative charged led attracts the gas bubbles faster, which as well shows us that the gas bubbles are positive (Hydrogen)

Final statement or rule:

$$2 H_2O (l) \rightarrow 2 H_2 (g) + O_2 (g)$$

electrolysis



Figure 7. Picture of Argumentation for Decomposition of Water Group 2.

concepts	evidence
A. less oxygen is being produced. Oxygen to hydrogen ratio is 1:2	A. both diatomic molecules, for e/ oxygen molecule being decomposed, there are 2 hydrogen molecules
B. Hydrogen is attracted to cathode.	B. hydrogen has positive charge, more bubbles on cathode
C. Oxygen is attracted to anode.	C. O_2 has negative charge, less bubbles on anode
d. light is produced into Na & Cl .	
E. Lead helps conduct electricity.	E. lead is a metal & metals are good conductors
f. hand generator converts kinetic energy to electrical energy	f. Electrical energy is needed to decompose water.
g. Salt in water forms electrolyte solution	g. Solution contains Sodium anions & Chloride cations.
h. electrical energy creates voltage difference between lead	h. caused by imbalance of charge. One is an anode & other is a cathode
I. less electrons flow through anode	I. Anode is positive.

Figure 8. Picture of the continuation of the Argumentation from Figure 7.

In the Golf Ball Ping Pong Ball discrepant event students made a claim first and then watched the demonstration. This process left many groups starting their claims with the ping pong ball bouncing higher until the students watched the demonstrations. In

Figure 9, the student originally changed the claim to adjust for the golf ball bouncing higher. In this argumentation the group focused on the composition of the golf ball and the ping pong ball to describe which would bounce higher. In addition, the group took the time to measure the mass and used that evidence as part of the argumentation. It was clear that the students were taking time to research information to help them with their evidence and justifications. This resulted in a more complex final statement.

Question / Purpose: Which one one is going to bounce higher?	
Our Claim: different the ping pong ball will bounce higher I think the golf ball will bounce higher than the ping-pong ball, because they are harder which means more force from gravity will be pushed on it to make them bounce higher.	
Our Evidence: - golf ball is harder. - golf ball is heavier. - more force is applied to the golf ball (gravity) to make them bounce higher. - has soft rubber elements to enhance durability	Our Justification of the Evidence: A ping-pong ball is lighter than the golf ball. ping-pong balls are made of celluloid a type of plastic. ping-pong: 2.7g. golf ball: 45.73g.
Final statement or rule: If a golf ball weighs 45.73 grams and a ping pong ball weighs 2.7 grams, then it is obvious that the golf ball weighs more. The more an object weighs when it hits the floor all the force being pushed on it to all the way to the ground is going to combine together and bounce higher from all the weight.	

Figure 9. Picture of argumentation for The Golf Ball / Ping Pong Ball discrepant event.

In Figure 10, the student again needed to change the original claim. In this argumentation, the student focused more on physics principles for the argumentation. The group used multiple concepts to argue what was happening in the discrepant event. In this case, the group tied chemistry and physics together for their final statement.

Question / Purpose: Which will bounce higher, ping pong or golf ball?	
Our Claim: ping pong balls higher golfball goes higher	
Our Evidence: The golf ball does go higher because it goes faster than the ping pong ball	Our Justification of the Evidence: the golf ball is not nearly as affected by air resistance as the ping pong ball is, since it is <u>so</u> light.
The ping pong ball, when struck on top of the golf ball flies off, but not the same amount the other way around.	When the golf ball is on the bottom, when it hits the ground it bounces because the impulse the is still happening. The reason the golf ball are moving through the force of the impulse and that momentum pushes the down in the ping pong ball away. Additionally, because the ping pong?
Final statement or rule: If an object is light enough it will fall slower than a regular object because air resistance plays a bigger part. Denser objects which have more atoms, have a longer impulse time than less dense objects, allowing the denser object to disperse more energy into the surface rather than bouncing.	

Figure 10. Picture of argumentation for The Golf Ball Ping Pong Ball discrepant event.

The Rusty Nail Misconception Probe gave the students an opportunity to work through misconceptions and correct them in Figure 11. Initially, some of the groups had selected the wrong answer. However, by the end of the evidence, justification, and oral argumentation the students had found their misconceptions and corrected them. Many of the groups used the balanced chemical equation to help them identify the increase in mass. Also present in the argumentation were definitions of rust to help with the balanced

equation. One of the students also tied oxidation into the final statement. This was a new concept that had not yet been covered.

Question / Purpose: Determine what the outcome of the probe is. A, B, or C.	
Our Claim: The mass of the dry, rusted nails will be more than the mass of the dry nails before they rusted.	
Our Evidence: Rust is iron oxide which is made from oxygen, so when the nails rust, they become heavier because of the oxygen which makes the mass heavier.	Our Justification of the Evidence: Definition of rust - a reddish or yellowish-brown flaky coating of iron oxide that is formed on iron or steel by oxidation, especially in the presence of moisture. Or balanced chemical reaction for rust is $4\text{Fe} + 3\text{O}_2 \rightarrow 2\text{Fe}_2\text{O}_3$.
Final statement or rule: Because rust is iron oxide, the oxygen is added and it increases the mass, making the rusted nails heavier.	
(This is a chemical reaction) (oxidisation) which is the chemical process of combining a substance with oxygen.	

Figure 11. Picture of argumentation for The Rusty Nail Misconception Probe.

Towards the end of my argumentation research, I had the students complete a lab activity, Calculating Moles Lab, without the argumentation process. Students fell back

into their old routine of writing conclusions that answer a question, or summarized what they did in the lab with few ties to the content or academic vocabulary in Figure 13. The lab showed a great deal of data that was collected and processed in Figure 12. However, when the evidence and justifications were not required, students did not spend the time to justify the data to use in their conclusions. It was also clear that the students spent more time answering the lab questions rather than looking at how that information tied to the content. In addition, the students had just finished the Mole Lab (Appendix G) where the argumentation process was used. The students could have incorporated it into this lab's conclusion as the two labs were related, but they did not.

CALCULATING MOLES LAB

QUESTION: How many moles of sugar and salt are contained in a packet of salt or sugar?

SAFETY: Wear goggles at all times. Dispose of the sugar and salt in the trashcan.

MATERIAL:
 2 salt packets 2 sugar packets electronic balance

PROCEDURES:

1. Obtain a weigh paper and place it on the electronic balance and zero the scale. Pour the entire packet of sugar onto the weigh paper.
2. Record the mass in the data table. Collect data from 2 other groups, so that you have 3 data points. Record these in your data table as well.
3. Use the molar mass ($C_6H_{12}O_6$) to calculate the moles in a sugar packet.
4. Use all 3 moles calculated to determine an average number of moles.
5. Repeat these steps with the salt packets ($NaCl$).

POST-LAB QUESTION:

1. Which packet was bigger?
2. Which packet had more moles? Explain.
3. How many grams of sugar would it take to make the same number of moles as the salt. Be prepared to explain this in your argumentation.

	mass	Group # 2	2 Pack	Group # 2
Sugar	2.89g	2.78g	5.55g	5.81g
Salt	.7g	.63g	1.35g	1.29g

	1 Pack	2 Pack
(sugar) $C_6H_{12}O_6$	$2.89g \times \frac{1 \text{ mol}}{180.15g} = .016 \text{ mol}$ $2.78g \times \frac{1 \text{ mol}}{180.15g} = .015 \text{ mol}$	$5.55g \times \frac{1 \text{ mol}}{180.15g} = .031 \text{ mol}$ $5.81g \times \frac{1 \text{ mol}}{180.15g} = .032 \text{ mol}$
(Salt) $NaCl$	$.7g \times \frac{1 \text{ mol}}{58.44g} = .012 \text{ mol}$ $.63g \times \frac{1 \text{ mol}}{58.44g} = .011 \text{ mol}$	$1.35g \times \frac{1 \text{ mol}}{58.44g} = .023 \text{ mol}$ $1.29g \times \frac{1 \text{ mol}}{58.44g} = .022 \text{ mol}$

	1 Pack	2 Pack	1 Pack	2 Pack
Sugar	.02 mol	.02 mol	Salt	.011 mol
				.02 mol

Figure 12. Picture of data collected for the Calculating Moles Lab.

Post-Lab questions

- Sugar had more moles in both packets because when the packets contents are weighed and then converted to moles we can see that there .02 moles in one packet of sugar and .02 moles in 2 sugar packets.

Figure 13. Picture of the completion of the Calculating Moles Lab conclusion.

In the Gas Laws Lab Argumentation, there was a wide range of evidence and justifications used, from drawings to the use of formulas. Students had a variety of content on their forms. In Figure 14, the student used the claim area to justify which gas law applied to the lab. In most cases the evidence and justification section did not have a lot of material listed. However, in the final statement the student tied all of the information together as well as explained the relationship of the gas law and how it applied to the lab.

Question / Purpose: What happens to the Marshmallow? What gas law explains the behavior?	
Our Claim: It can not be the ideal gas law cause the temp. doesn't change and it can't be the combined gas law For the same reason. It's Boyle's law because the pressure and volume of a gas have an inverse relationship, when temp. is held constant.	
Our Evidence: • Deforms the marshmallow • Gets Bigger when you release the pump. • Gets smaller when you pump.	Our Justification of the Evidence: • Pressure is released. • Putting in a lot of pressure.
Final statement or rule: the Boyle's law describes inverse Proportional relationship between the absolute pressure and volume of the gas if the temp. is kept constant within a closed system such as the marshmallow in the syringe.	

Figure 14. Picture of argumentation for The Gas Laws Lab.

Chemistry Attitudinal Survey Data

The second part of the data collected was the Chemistry Attitudinal Survey that was given to the students in December 2015 and in May 2016. This data helped address the primary research question and looked at how student understanding was improved. It also addressed student perception of the argumentation process. The results were compared and analyzed between the two time periods for any differences in the responses. The surveys were designed to separate the classes, period 2 verses period 3 and male verses female. However, once the raw data was processed there were no clear result differences between the groups. The data was combined for all groups and periods, and the results were only compared between December and May Table 2.

Overall, the data for both December and May showed positive results. There were only small changes that are apparent in Table 2. Question one, I enjoy my science class, had the largest percentage of responses in the agree column in December. It showed a small shift from the agree columns to the disagree columns between the two survey periods. Question two, doing labs is fun for me, showed more students had moved to the agree column in May. Question three, I learn science best through lectures and bookwork, showed more polarizing results with more students moving from disagree to agree, or in the opposite direction strongly disagree. Question four, I learn science best through doing labs, showed movements from disagree to agree or strongly agree. Question five, I understand the purpose of labs and how it relates to the material we are learning, showed movements from agree to either strongly agree, or disagree. Question six, questions that follow labs often help me to understand the scientific concepts of the

labs, showed a movement from agree to disagree and strongly disagree. Question seven, writing conclusions is easy for me and I can explain what I have learned, showed movements into both agree and disagree columns. Question eight, I participate more when I work in groups than when I work alone, showed a movement from disagree to agree and strongly agree columns. Question nine, listening to others helps me to understand the material better, had students moving out of the agree column to either strongly agree or disagree. Question ten, solving problems is easier when I work in a group, showed movements to agree and strongly agree columns. Question eleven, hands-on activities make science more enjoyable, showed movement from agree to strongly agree.

Table 2
Percentage Summary for Chemistry Attitudinal Survey Questions 1-11

Percentage %	December Strongly Agree	December Agree	December Disagree	December Strongly Disagree	December No Answer Given	May Strongly Agree	May Agree	May Disagree	May Strongly Disagree	May No Answer Given
Question 1	11	68	16	4	2	8	66	23	4	0
Question 2	30	57	9	2	2	26	68	4	2	0
Question 3	11	29	43	16	0	8	38	8	28	0
Question 4	20	50	29	2	0	26	51	19	2	2
Question 5	16	80	4	0	0	23	66	8	2	2
Question 6	14	63	23	0	0	9	62	25	2	2
Question 7	13	45	32	9	2	9	49	36	6	0
Question 8	38	38	21	4	0	49	38	13	0	0
Question 9	20	63	16	0	2	38	34	26	0	2
Question 10	32	52	13	4	0	49	38	11	2	0
Question 11	46	50	4	0	0	64	36	0	0	0

Table 3 notes significant changes in question 3, 9, 10, and 11. Question 3 shows a significant drop in the disagree responses at a -35%. Question 9, shows a significant change in the agree responses at -29%. Questions 10 and 11 show significant gains in strongly agree columns and decreases in the agree columns.

Table 3
Percentage Change between December and May for Chemistry Attitudinal Survey
Questions 1-11 Percent Change = May% - Dec.%

Percent % Change	Strongly Agree	Agree	Disagree	Strongly Disagree	No Answer Given
Question 1	-3	-2	7	0	-2
Question 2	-4	11	-5	0	-2
Question 3	-3	9	-35	12	0
Question 4	6	1	-10	0	2
Question 5	7	-14	4	2	2
Question 6	-5	-1	2	2	2
Question 7	-4	4	4	-3	-2
Question 8	11	0	-8	-4	0
Question 9	18	-29	10	0	0
Question 10	17	-14	-2	-2	0
Question 11	18	-14	-4	0	0

Questions twelve through sixteen were free response questions. A bar graph was used to summarize the percent of similar answers for each of the questions. The answers were compiled according to the general answers and compared between the changes in December and May. For question twelve, answers were very similar between December and May (Figure 15). However, in May more reasons were given for why teachers gave labs. The biggest gain was in the area of helping with understanding at a seven percent gain. Nine percent of the students identified that labs could be a form of checking for understanding. There was also a drop in fun and enjoyment by eight percent.

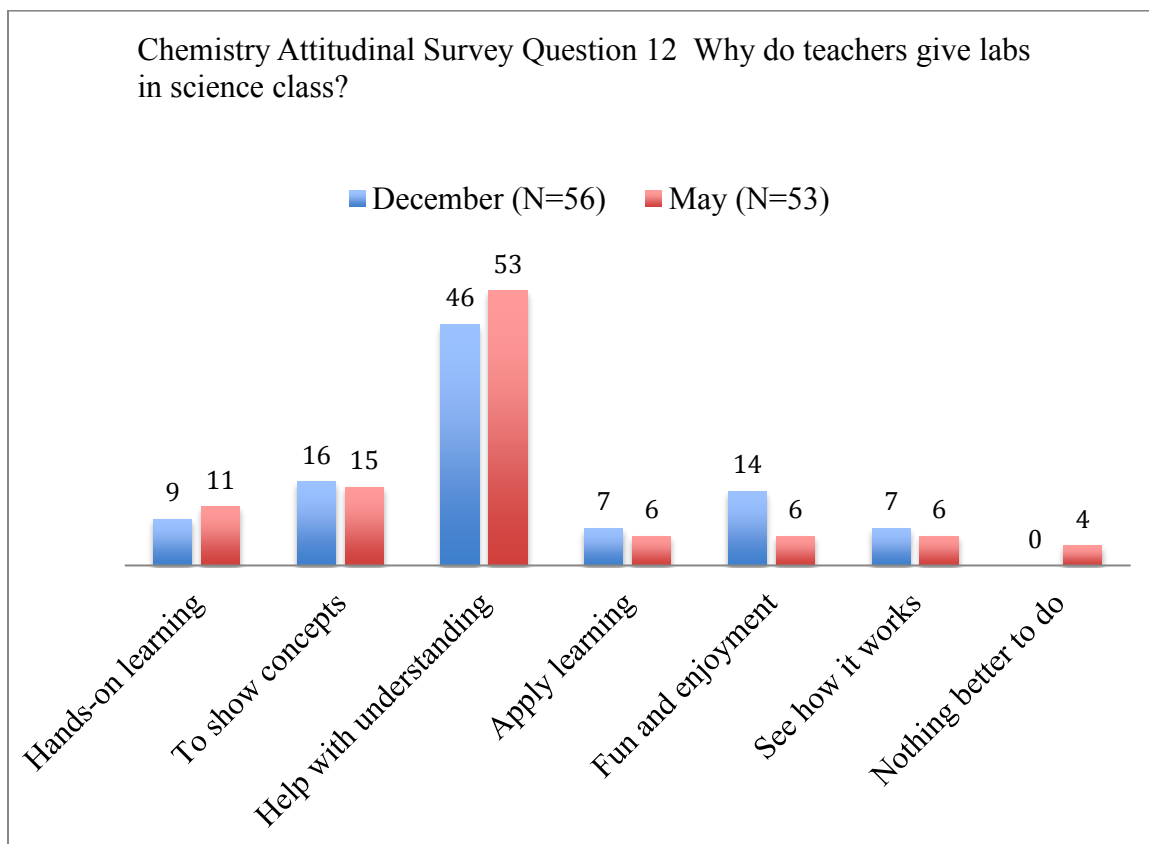


Figure 15. Responses Chemistry Attitudinal Survey Question 12 given in December, (N=56) and May, (N=53).

In question thirteen, students identified how well labs helped them understand chemistry. In both December and May, the majority of the students selected that labs helped them with understanding (Figures 16). However, in May, there was a shift from helping with understanding to helping somewhat. Also evident in May was a new topic showing four percent of the students realize that labs would show them how chemistry works.

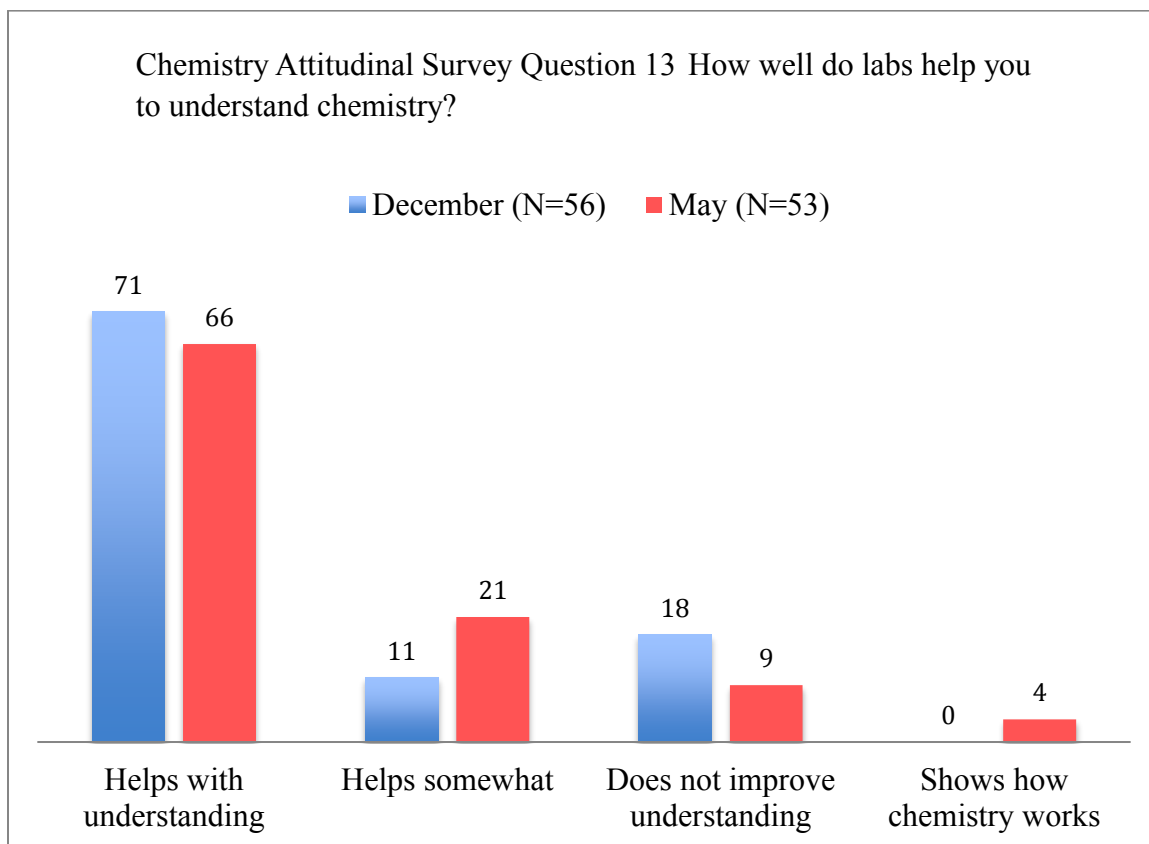


Figure 16. Responses Chemistry Attitudinal Survey Question 12 given in December, (N=56) and May, (N=53).

In question fourteen, students were asked to comment on their motivation level in regards to working in a group. For both December and May, the majority of the students stated various reasons for why groups helped to motivate them (Figures 17). The results in May showed that fewer students wanted to work alone after the argumentation process. Also present in the May results were more comments as to why the groups did not motivate the students. Many of these comments focused around the students' abilities to work together and help each other. There was a 12% gain in those who were motivated by help, and a 15% gain in those who were motivated by the group counting on them.

Also relevant was the drop in students who were motivated by comparing and sharing.

Students now saw this as helping each other.

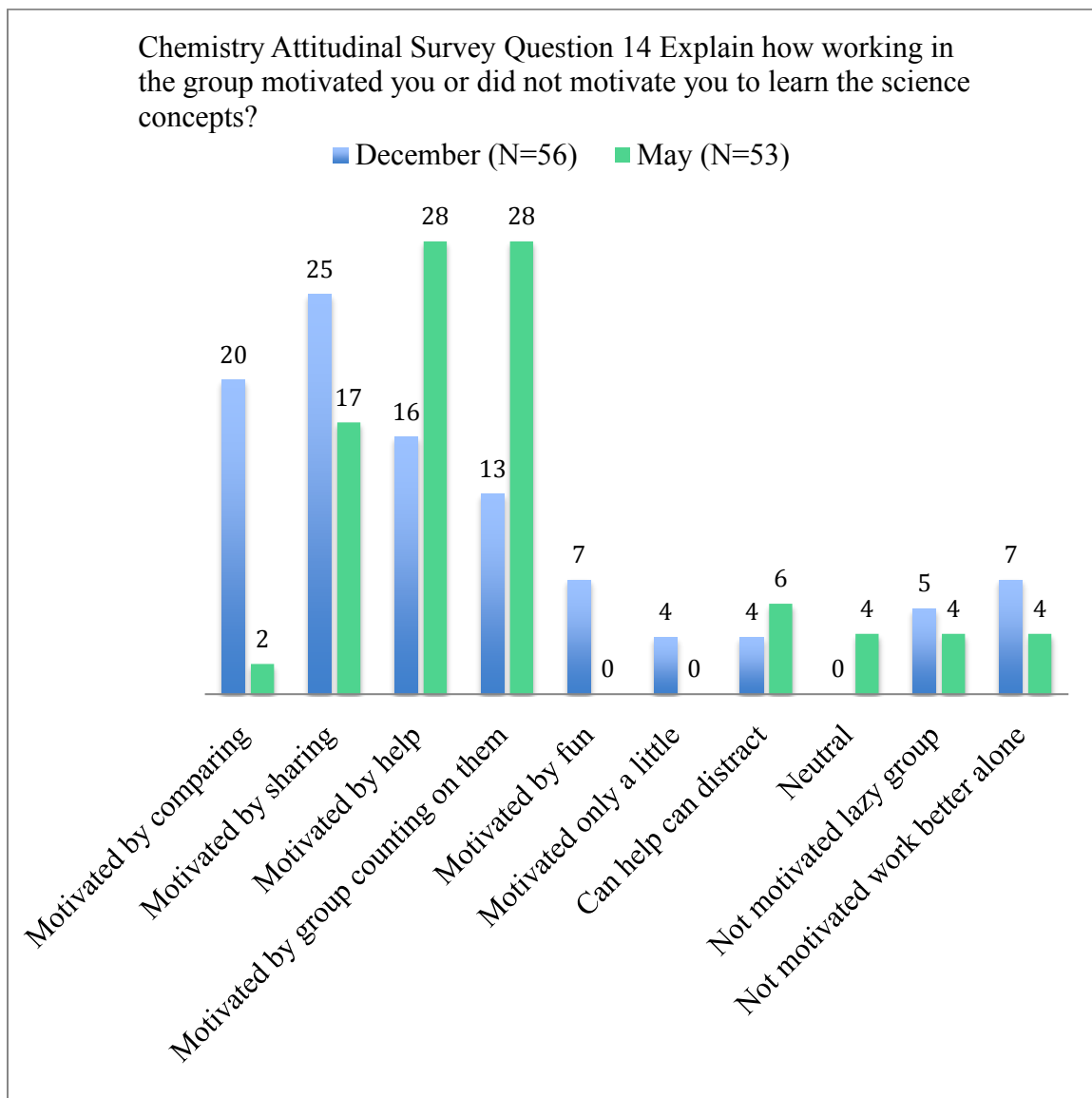


Figure 17. Responses Chemistry Attitudinal Survey Question 14 given in December, (N=56) and May, (N=53).

Question fifteen focused on the most difficult part about working with a group.

The results showed many similarities between December and May. The largest category, for both time periods, was people not wanting to work, from 47% to 50% (Figure 18).

However, there was a three percent drop in this category, showing more people working over the argumentation time period. In May, there was a greater percentage that noted communication was the hardest part of working in the group. May also showed fewer students were distracted, and that the argumentation process was the hardest part of working in the group.

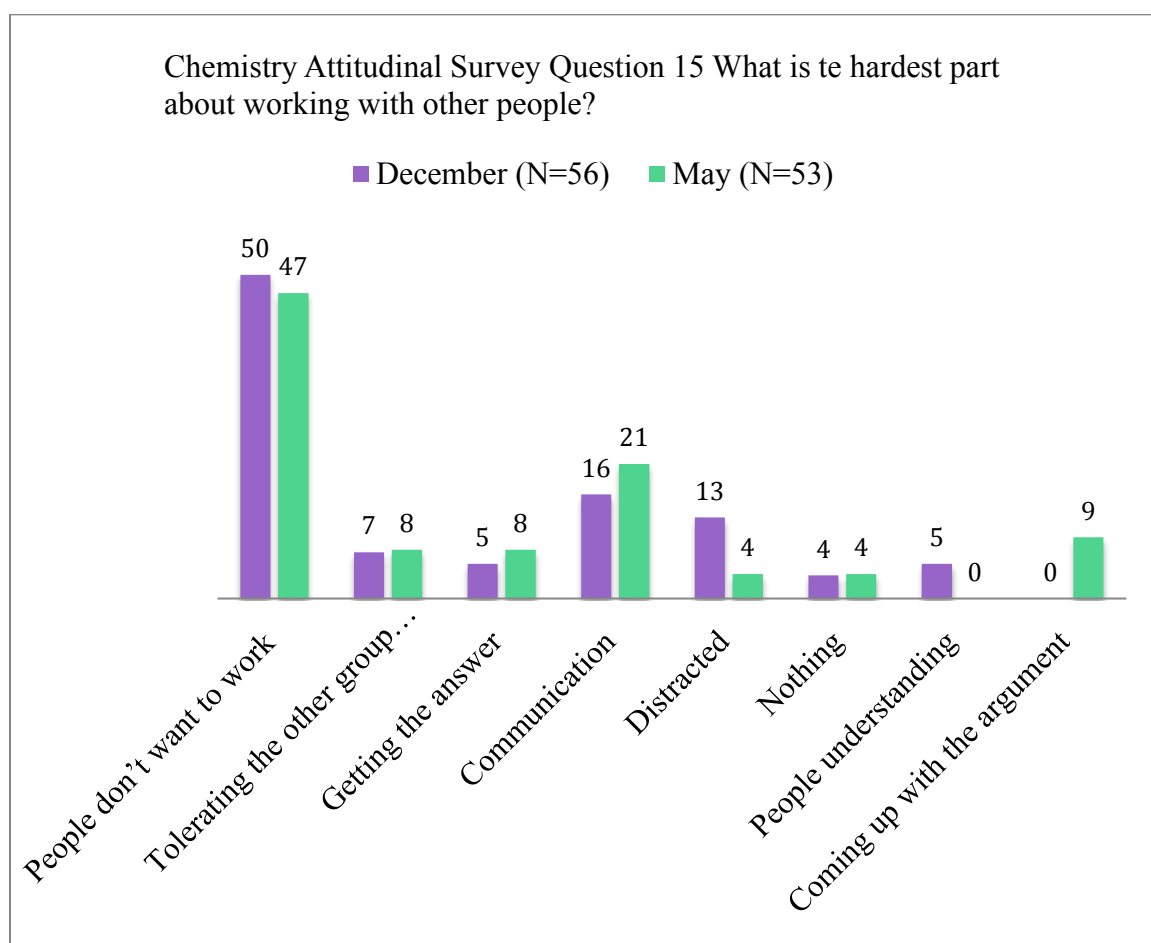


Figure 18. Responses Chemistry Attitudinal Survey Question 15 given in December, (N=56) and May, (N=53).

Question 16 addressed what was the best part about working with others. This question showed some significant changes between December and May. In December,

18% of the students said the best part was that it was more fun (Figure 19). In May, only 8% said it was more fun for a change of 10%. There was a 21% drop in the response, had help, as the best part. In May, 45% stated that they learned better when working in a group, for a gain of 31%. In December, 5% of the students stated that it takes less time, while in May, 21% of the students stated it took less time when the students were working together.

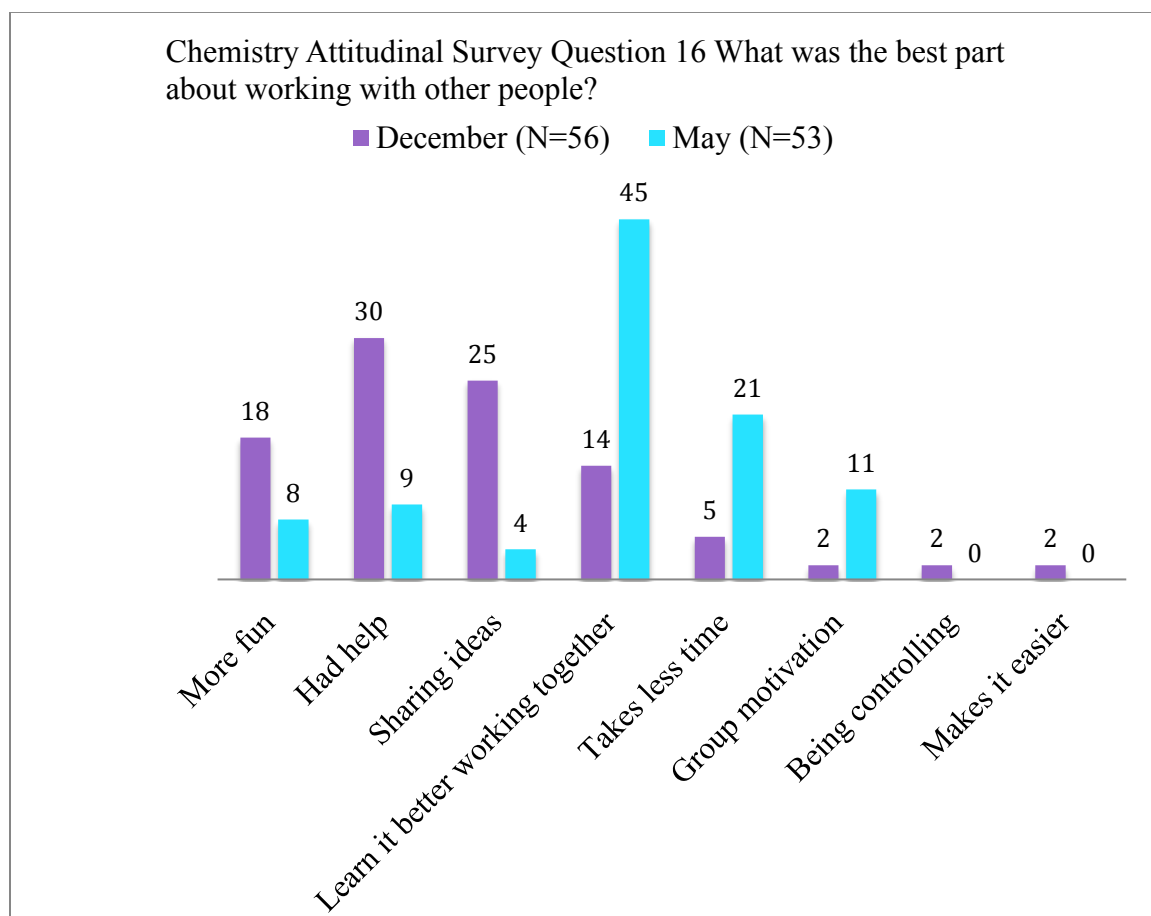


Figure 19. Responses Chemistry Attitudinal Survey Question 16 given in December, (N=56) and May, (N=53).

The next set of figures summarized information from the Pre-Argumentation and Post-Argumentation surveys. This data helped assess how well argumentation improved student understanding as well as the student perception of argumentation. Questions one and two were the same question on both surveys. Question three through five on the Post-Argumentation survey addressed the argumentation process, so answer responses varied between the two surveys.

Question one addressed what was the hardest part about writing a laboratory conclusion. In December, 63% of the students stated knowing what to write was the hardest part (Figure 20). In May, only 34% of the students stated the hardest part was knowing what to write, showing 28% of the students knew what to write after the argumentation process. Understanding the lab received 15% of the comments in December, and 19% of the comments in May, for a change of 4%. Summarizing and answering the questions shifted from 4% in December to 19% in May. In May, eight percent of the students were concerned about getting all of the concepts. Also present in May, was that 8% of the students were concerned about finding and justifying the evidence.

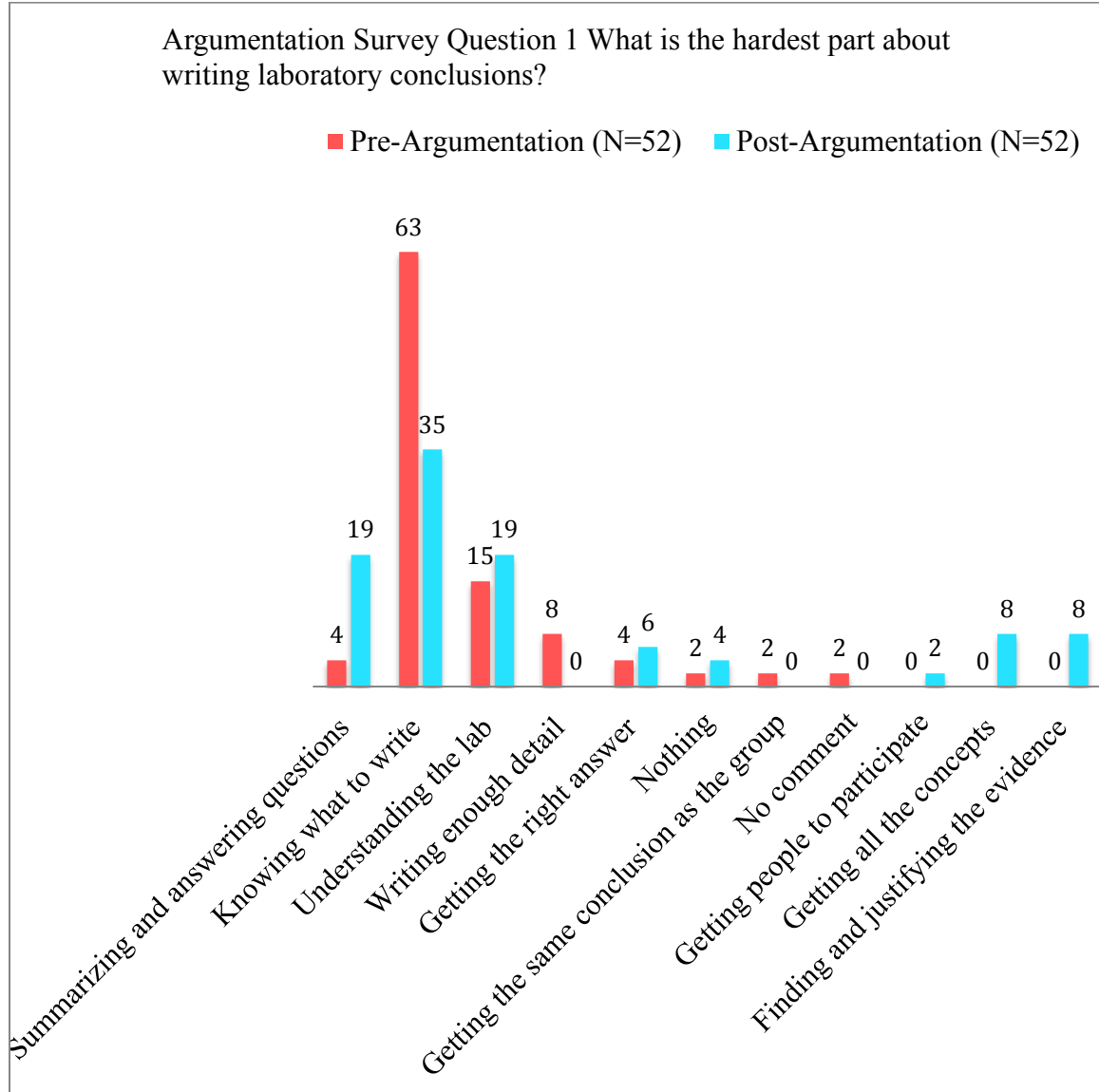


Figure 20. Responses Pre-Argumentation and Post-Argumentation Surveys Question 1 given in December, (N=52) and May, (N=52).

Question two addressed if the students felt they had a better understanding of the material when they finished the lab or argumentation process. In December, 42% of the students stated yes, while 33% of the students stated sometimes (Figure 21). In May, 58% of the students stated yes for a change of 16%, while only 13% of the students stated sometimes for a change of 20%. However, the May results showed a shift of 21% of the

students who stated that they did not understand, while December only had 17% of the students who made that statement.

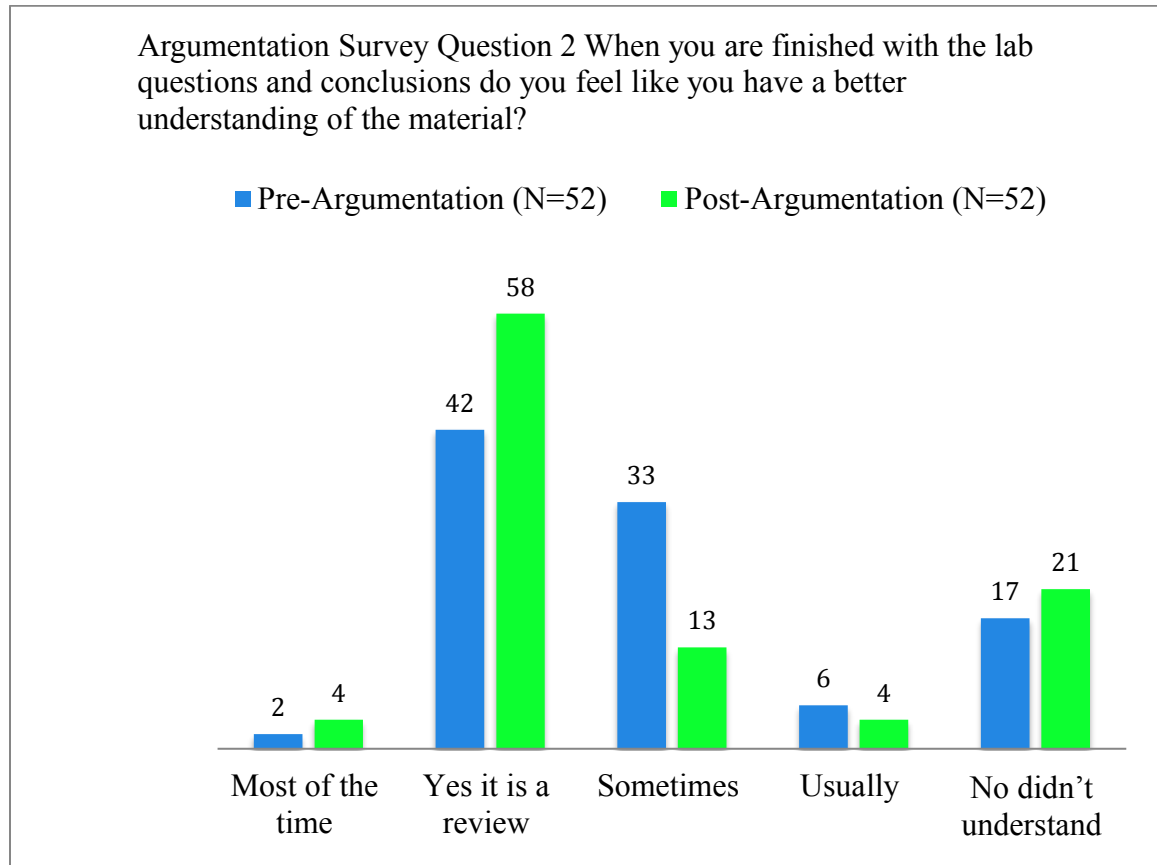


Figure 21. Responses Pre-Argumentation and Post-Argumentation Surveys Question 2 given in December, (N=52) and May, (N=52).

Regarding Question 3, on the Pre-Argumentation Survey, the students were asked to explain if they liked working in groups and why. The majority of the students preferred groups, with 56% stating it helped to share ideas, while only 7% of the students wanted to work alone (Figure 22). The next largest group was 31% of the students who liked groups so they could share work and ideas.

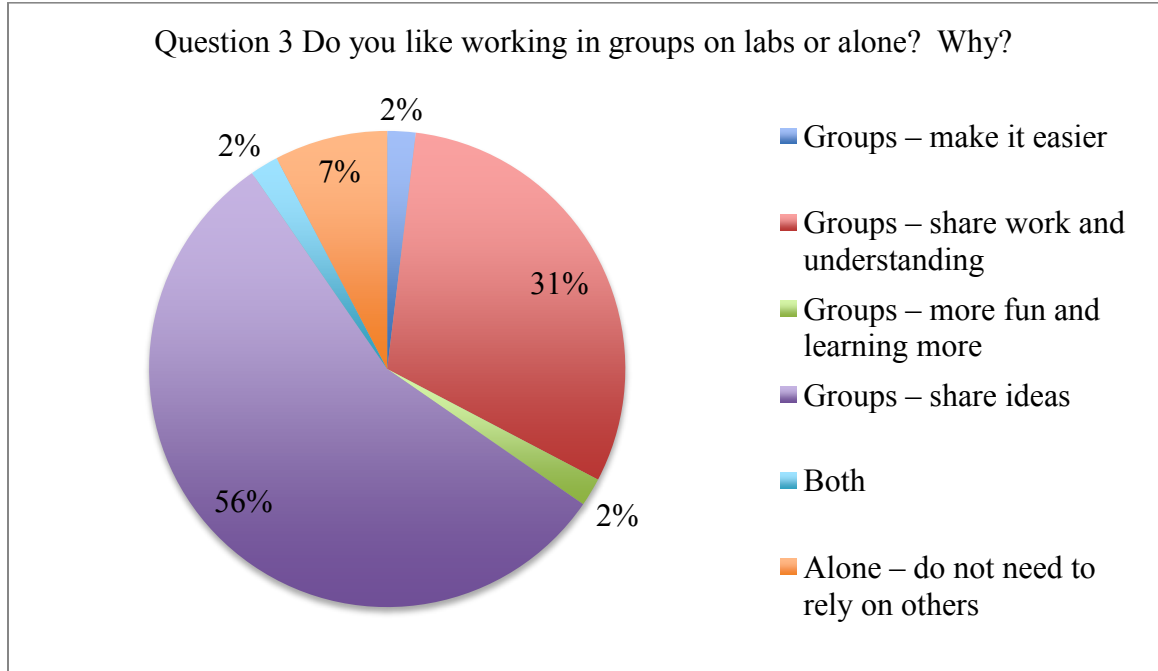


Figure 22. Pre-Argumentation Survey Question 3 given in December, (N=52).

Question three on the Post-Argumentation asked students if they liked working in groups on the argumentation. Forty-one percent of the students stated yes, it helped with understanding (Figure 23). The next largest group was 26%, stating that the group helped to develop the argument. There was still a group that would prefer to work alone, at 9%.

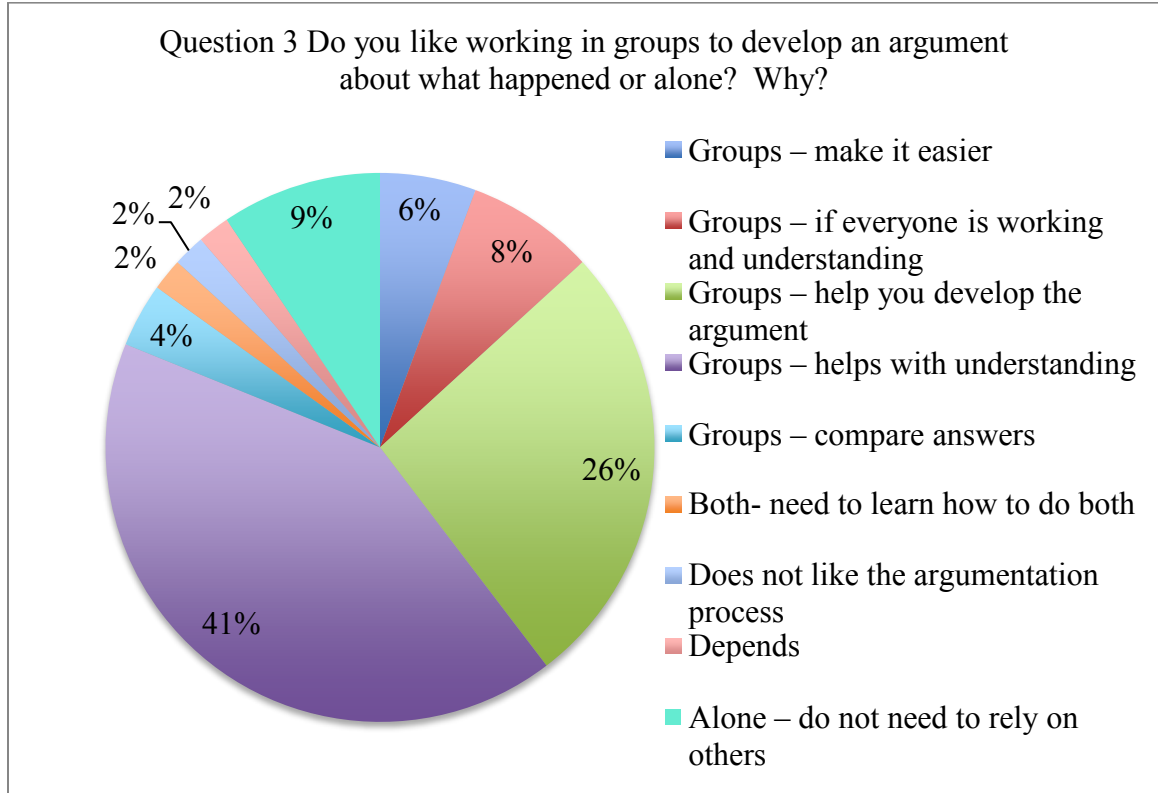


Figure 23. Post-Argumentation Survey Question 3 given in May, ($N=52$).

Question 4 on the Pre-Argumentation Survey asked students what they would change about labs. The largest majority, at 27%, stated they liked them and would not change them (Figure 24). The next largest group was 15%, stating that more time was needed. The next category was 14%, stating that they would like less math and writing. The more instructions group, at 12%, was the next largest.

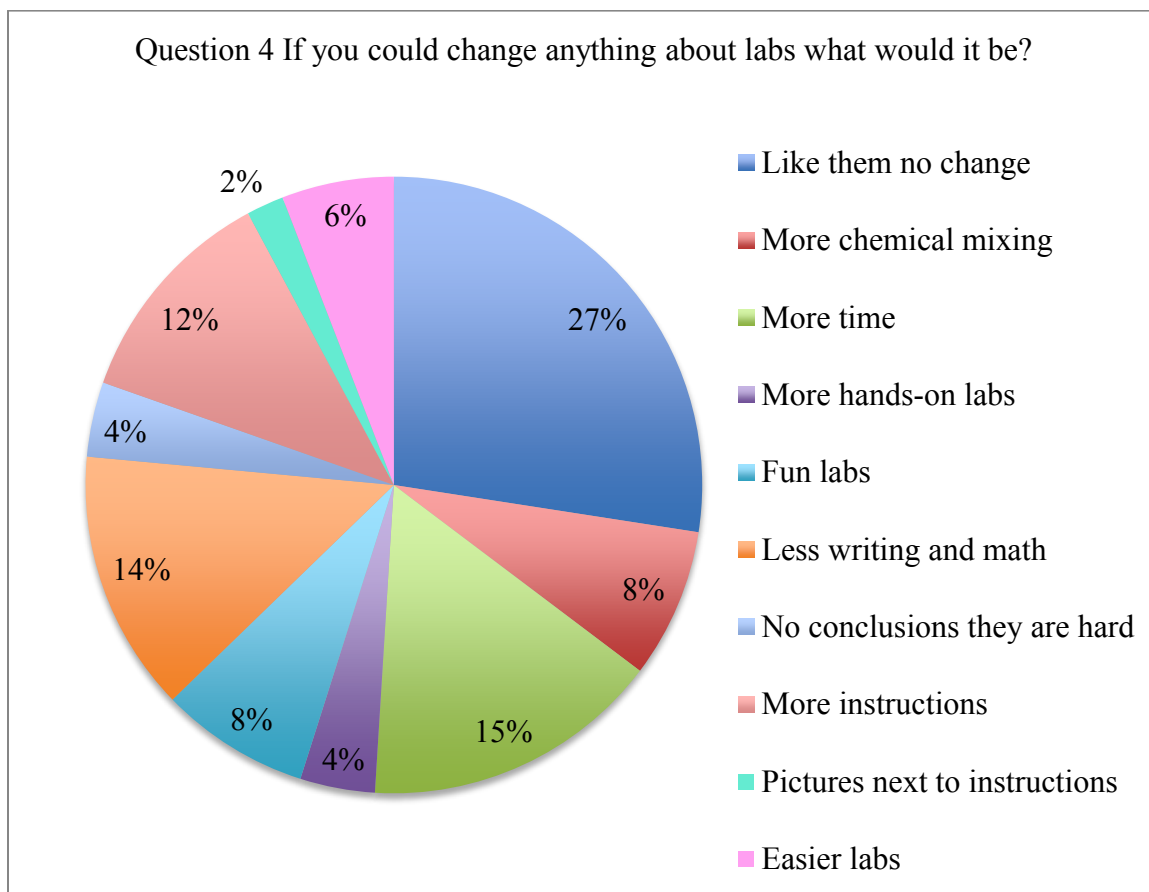


Figure 24. Pre-Argumentation Survey Question 4 given in December, (N=52).

Question four on the Post-Argumentation, asked students if listening to all of the groups present their arguments helped them improve their own arguments. The majority, at 46%, said yes they obtained new perspectives and understandings, with 15% stating yes but no explanations were given (Figure 25). Another group, at 24%, stated sometimes or occasionally they learned something new. Fifteen percent stated no it did not help.

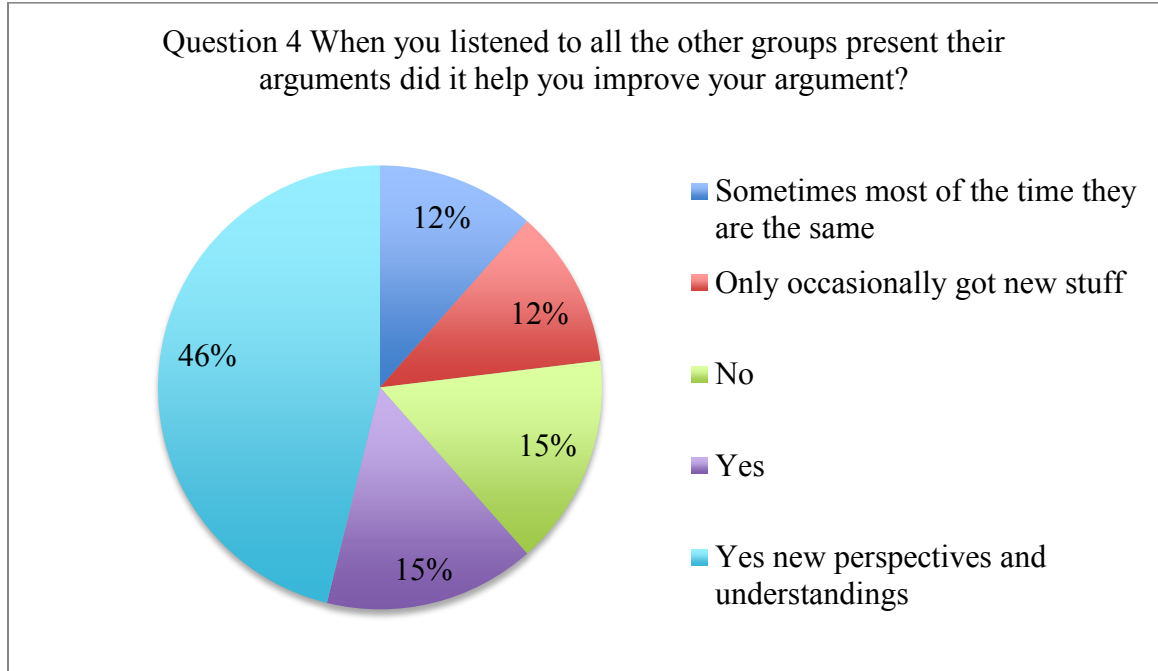


Figure 25. Post-Argumentation Survey Question 4 given in May, ($N=52$).

Question five, on the Post-Argumentation, asked students if after the argumentation process, was it easier to answer lab questions and write a conclusion. The largest majority, at 63%, said yes they had a better understanding after the argumentation, and 6% stated it helped with questions but not the conclusion (Figure 26). Seventeen percent of the students stated they sometimes got a better understanding. Six percent of the students stated that they were still confused.

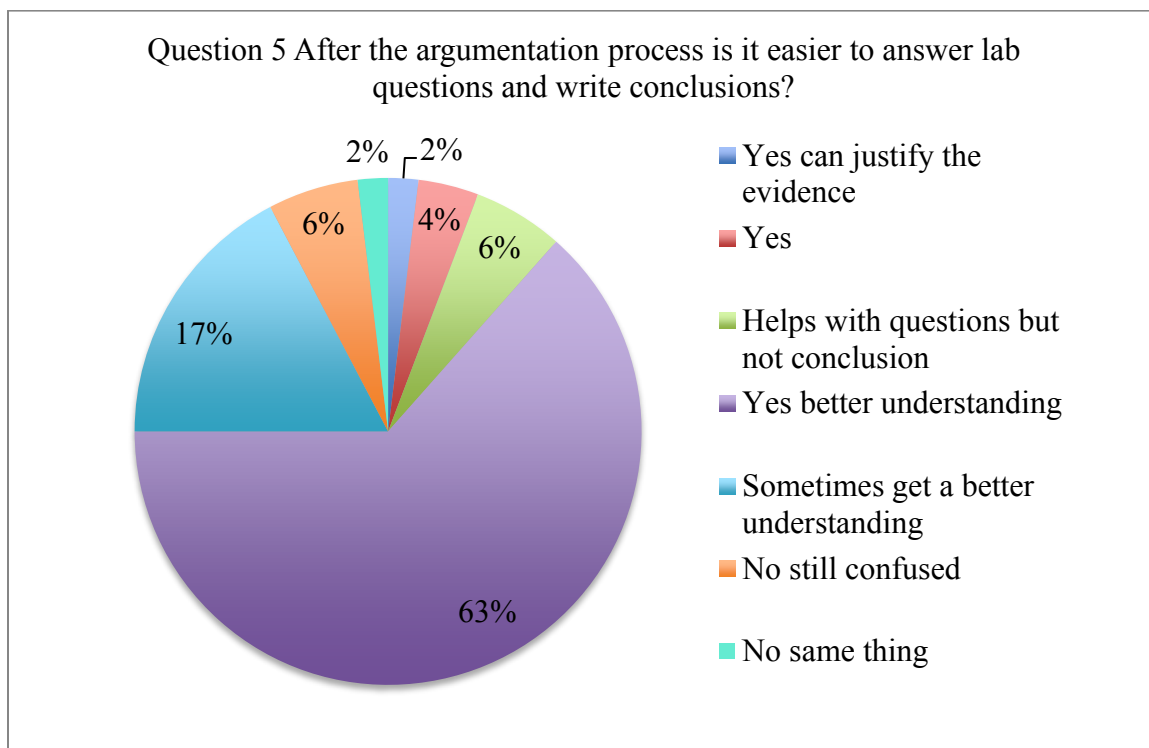


Figure 26. Post-Argumentation Survey Question 5 given in May, (N=52).

INTERPRETATION AND CONCLUSION

Will the use of argumentation in Argument Driven Inquiry improve the students' understanding of the concepts being covered in a laboratory investigation? The answer to this primary research question had a very clear positive result? The data collected from the argumentations showed an immediate improvement in the conclusions. The Balanced Equation Argumentation showed a lack of evidence and justifications for many of the groups. However, what was present was an increase in academic vocabulary in the final statements and evidence that students were listening to their peers to improve their arguments. The Decomposition of Water Lab showed a significant increase in the evidence and justification data tables. Groups worked to compile lists of concepts that the lab addressed and then worked them into their argumentations. Throughout the

process each argumentation period resulted in new concepts being discussed, and the use of a variety of methods to represent and justify the evidence. And, all of this varied by group.

The argumentation process helped to give lab activities more meaning, and they offered more rigor. One of the most meaningful parts of the argumentation process was that the students had to perform an oral argument. This oral argument was in essence a performance assessment. As I have observed in the past, students worked harder when they were being assessed on their performance. Since part of the oral presentation involved everyone in the group, all students had to take an active role, each presenting at least one part of the argument. The data on the Chemistry Attitudinal Survey showed help from their peers motivated 12% of the students, and 15% were motivated by the group counting on them. As observed in the research the process moved the students from a passive learners' role into an active learners' role where they took responsibility for their learning (Anderson, 2002). This forced students out of the passive learner role and into the active participant role. It also moved labs from fun and games into a learning setting.

Many of my students came in with the expectation, from previous classes, that labs were fun and a playtime with few requirements to tie the learning to the content being covered. As the students worked through the argumentation process, having to explain and justify the evidence with as much science content as they could, the playtime was over and learning had to occur. Some students welcomed this process, while others complained about it. I believe that this was the reason that there was a shift in the data in

question three on the Chemistry Attitudinal Survey in May. For some students bookwork and lectures was easier than the processing skills they had to use in the argumentation process. Van Rens, Pilot, & van der Schee, 2009, classified three primary areas – willingness, ability, and knowing – as a requirement for success. All of these areas were constantly being developed during the argumentation process. Students were willing because they knew the group was counting on them and they did not want to let the group down. Because the labs were now done in groups, those students who struggled with the ability level now had help. The group argumentation process resulted in the students knowing what to write at the end of the lab. The Argumentation Surveys showed 28% of the students knew what to write in a conclusion by May. While I still had students who did not know what to write, that number was only 3% of the students in May. Sixteen percent of the students were focused on getting all the concepts and finding and justifying all the evidence.

In the Chemistry Attitudinal Survey, question five showed movement towards disagree on the responses. This was most likely due to the increase in rigor of the class and labs that used the argumentation process. The actual labs did not become more difficult. However, as the process required all students to be active learners, for some students this was a challenge. These students were not comfortable being active participants and in many cases had a history of not turning in the labs. Now the group was counting on them and they had to deliver part of the argument, so sitting back and watching was not a viable option. This shift in roles was stressful for some students, especially if they did not understand what was being done or explained. Question eight

illustrates this with the change in the percentage of students strongly agreeing, and agreeing (Tables 2 and 3). The argumentation process relied heavily on the group working together to develop the argument. This was also why so many of the free response questions on the Chemistry Attitudinal Survey had comments on all members of the group working together as seen in Figures 18.

Regarding question nine on the Chemistry Attitudinal Survey related to listening to others, as the students listened to their peers it helped them to gain a greater understanding of the lab content. More students moved into the strongly agree column in May. The process of argumentation based on the evidence collected during a laboratory activity may have helped the students develop a better explanation, similar to the practices of scientists (Berland & McNeil, 2012). As the students had discussions in their groups and worked together, struggling students were able to understand concepts that they would have missed, or would not even have tried to understand in the past. Listening to all of the oral arguments also allowed students to hear new concepts that their group did not see, and incorporate that into their final statements. However, question nine also had movement into the column labeled disagree. I believe this was why so many of the free response questions had comments regarding group communication. Communication also proved to be an additional area where students had to work harder to improve. This process required a great deal of discussion on the students' part. Some groups did this well while other groups struggled at times. It was interesting to see which groups came up with the best arguments with the most evidence and justifications. At times, it was not always the strongest students who came up with

these arguments. This was a surprise to me and I was fascinated by the detail some groups were able to develop. However, more complex arguments made it harder for some students to understand the concepts and how they related to the lab. They felt left out of the conversation at times and unable to understand. This was apparent in Figure 26 where 6% of the students were still confused.

In their 2005 study, Kuhn and Reiser found that when students have an opportunity to communicate their understanding to their peers they were able to assess the strengths and weaknesses of their understanding. I found that my stronger students gained a greater understanding by explaining to their peers. In Figure 25, 46% of the students stated that listening to the other groups gave them new perspectives and understanding, and 15% stated yes without an explanation. My weaker students were able to have an understanding because they had help. Most of my higher performing students were in the 12% that said they only occasionally obtained a new concept by listening to the other groups.

Can the argumentation process be used with multiple formats of laboratory activities, inquiry activities, misconception probes, and discrepant events? For me, the answer to this secondary research question had a clear yes. Evidence for this is depicted in Figures 1 through 14. The process worked regardless of the type of activity. The Claims and Evidence worksheet was also a key component. Without this requirement students were not conscious of the evidence, or of justifying it. This was clear with the Calculating Moles Lab where the argumentation process was not used. Immediately students fell back into their old habits for writing conclusions. One area of concern was

the connection between the oral discussion in the laboratory group and the final written report (Kuhn, & Reiser, 2005). This point, raised by Kuhn and Reiser, was not an issue for my argumentation process. I believe that was due to the Claims and Evidence worksheet. While the students were discussing, they were also writing. The end of the discussion resulted in the students having a written product to accompany their oral presentation. Most of the students used the worksheets during the oral presentations. The final statement was written out before the oral presentation. Students also had an opportunity to change these final statements before they turned in their labs if they heard new information that they wanted to incorporate.

What is student perception of argumentation? This secondary research question was summarized on The Chemistry Attitudinal Survey, and the Pre-Argumentation and Post-Argumentation Surveys. The Chemistry Attitudinal Surveys for the most part have positive answers (Table 2). My students like their science class and have fun doing labs. While there are some small changes in the agree to the disagree columns due to the increased rigor in content from December to May, overall the attitude was positive (Table 3). Question 3 was where I saw the biggest changes. Students went from saying they do not learn from textbooks and lectures in December to saying that they learn better from textbooks and lectures in May. Students realized that labs were as challenging and demanding as learning from a textbook or a lecture. The strongly disagree response also increased as students also realized how much they could learn from labs.

When comparing the results of the Pre-Argumentation surveys verses the Post-Argumentation surveys, the first big difference was in question one. In December 63%

of the students stated the hardest part about writing a laboratory conclusion was knowing what to write. In May, that same response was only selected by 34% of the students. After the argumentation process, students had a written conclusion and they had the opportunity to change that conclusion based on what they heard from the other groups. A significant number of students realized that they now had a conclusion done. Ideally this number would be much smaller than 34% but it was a huge decrease from the original 63%. Also, present in the same area is the response to question two, relating the completion of the questions and conclusion to the completion of the argumentation process. In December, 42% of the students stated that once they had finished the questions and conclusion, they had a better understanding of the material. In May, 58% of the students stated that they had a better understanding of the material once they finished their argumentation process. This shows a 16% increase in the student understanding when the argumentation process was applied.

The last two questions in the Post-Argumentation process deal with the argumentation process and were only answered in May. I had my doubts as to whether or not the students were listening to their peers. I assumed they were worrying about their own arguments. The results from question four helped to clarify this for me. For 24% of the students, listening to the arguments only sometime resulted in them gaining new information. This was true as many of the arguments were similar from one group to the next for many of the labs. However, there were times when one group would have a new insight with considerable detail that the other groups did not have. One group said yes at 15% with no explanation given. Another group 46% said yes, that it gave them new

perspectives and understanding. This was a total of 61% of the students attained a benefit from listening to the other groups (Figure 20). Also, following along the same lines, was the 63% of the students who stated that it was easier to answer lab questions and write a conclusion after the argumentation process (Figure 21).

Will the argumentation process better prepare students for the rigors of common core? The answer to this, the last of the research questions, was directly tied to the Claims and Evidence form. As students completed this form, recording evidence and making justifications, they were preparing for common core tasks. The ability to justify answers for evidence that they collected helped the students use higher level thinking skills. However, the treatment period was not long enough to make this a habit.

VALUE

Based on the results, I am satisfied that the argumentation process was valuable to my class instruction. For the first time I felt like students were gaining an understanding of the concepts being covered in laboratory time. Students developed conclusions utilizing the evidence collected in the data and wrote a justification for the evidence that tied to the concepts being taught. The drawback was that it added an additional day to laboratory time for the preparation and argumentation process. I also identified the need to streamline the grading rubric and develop one that could be checked off as the students presented their oral argumentation. Assessment took a considerable amount of time and was not realistic for a continual process.

While this research was completed in a high school chemistry class, it is applicable to other science classes. I used the Evidence Claims worksheet with my son's

fourth grade class during some hands-on activities that I did with the class. Some of these activities were the same ones that I did with my high school chemistry class. While I did not do the formal argumentation process with the fourth grade class, I did use the Claims and Evidence form, and had a class discussion following the experiments. It was clear that it would take some time to help these students collect and justify the evidence. However, they were able to find some evidence, and were able to state justifications for part of their evidence.

I will continue to use the argumentation process in my science classes. I will need to make modifications to the grading rubric allowing me to streamline it for efficiency and include an oral argumentation grade sheet. The grade sheet can be developed so that it will have check boxes to speed up the assessment time.

REFERENCES CITED

- Anderson, R. (2002). Reforming Science Teaching: What Research says about Inquiry. *Journal of Science Teacher Education*, 13(1), 1-12.
- Berland, L., & McNeil, K. (2012). For Whom is Argument and Explanation a Necessary Distinction? A Response to Osborne and Patterson. *Science Education*, 96(5), 808-813.
- Branan, D., & Morgan, M. (2010). Mini-Lab Activities: Inquiry- Based Lab Activities for Formative Assessment. *Journal of Chemical Education*, 87(1), 69-72.
- Criswell, B. (2012). Framing Inquiry in High School Chemistry: Helping Students See the Bigger Picture. *Journal of Chemical Education*, 89, 199-205.
- Dobson, R. (2014). The Effects of Scientific Explanation Instruction on Extended Response Performance by Eighth Grade Science Students. (Unpublished Professional Paper). Montana State University, Bozeman, Montana.
- Horton, M. (2011). Take-Home Chemistry 50: Low-Cost Activities to Extend Classroom Learning. Arlington, VA, National Science Teachers Association. 145-146, 163-164, 165-166, 215-216, 221-222.
- (2015, March). In *Venture Academy Family of Schools*. Retrieved March 14, 2015, from <http://www.ventureacademyca.org/home.aspx>
- Keeley, P., Eberle, F., and Farrin, L. Uncovering Student Ideas in Science. 2005. National Science Teachers Association Press, United State of America. 91.
- Kuhn, L., & Reiser, B. (2005). Students Constructing and Defending Evidence-Based Scientific Explanations. School of Educations and Social Policy Northwestern University, Dallas, Texas.
- Van Rens, L., Pilot, A., and van der Schee, J. (2009). A Framework for Teaching Scientific Inquiry in Upper Secondary School Chemistry. Center for Educational Training, Assessment, and Research VU University of Amsterdam, Amsterdam, The Netherlands. Center for Science and Mathematics Education, Utrecht University, Utrecht, The Netherlands.
- Van Rens, L., & Van der Schee, J. (2009). Teaching Molecular Diffusion Using an Inquiry Approach. *Journal of Chemical Education*, 86(12), 1437-1441.
- Walker, J. & Sampson, V. (2011). Learning to Argue and Arguing to Learn: Argument Driven Inquiry as a Way to Help Undergraduate Chemistry Students Learn How to Construct Arguments and Engage in Argumentation During a Laboratory Course. *Journal of Research in Science Teaching*, 50(5), 561-596.

APPENDICES

APPENDIX A
RUBRIC FOR GRADING CONCLUSIONS

Rubric For Grading Conclusions and Evaluations

AREA	SCORE = 1	SCORE = 2	SCORE = 3	SCORE = 4	SCORE = 5 Extra Credit
Quality of observation	One or two words are used in the observation.	Some description is used but the meaning is unclear based on the quality of writing.	Describes many of the details, can almost form a mental picture.	Observations have great detail. A mental picture is easy to obtain from the description.	W.O.W. a work of wonder goes above and beyond what is required.
Quality of Explanation	No explanations are given for the observation.	Two observations are explained with a reasoning given for each explanation.	Three or four observations are explained with reasoning and interpretation given for some explanations.	Five or more observations are explained with reasoning and interpretation given for all explanations.	All observations are interpreted and explained clearly with sound reasoning.
Oral Presentation of Argument	The student only briefly participates.	The student has a part in the explanation and delivers one concept.	The student delivers two concepts an explanation.	The student delivers two or more concepts and ties the explanation to the content.	The student's delivery goes above and beyond all expectations of the task.
Written Argument	The explanation is not clear.	The explanation covers two or less concepts.	The explanation covers three concepts but is not complete.	The explanation has four or more concepts and is complete.	All of the concepts are explained completely.
Tie to Content	There are one or no ties to the content.	There are two ties to the content but the ties are not clearly explained.	There are three or more ties to the content and the ties are explained but not complete.	There are four or more ties to the content and the ties are clearly explained.	All of the ties to the content are made and the ties are above and beyond what is expected.

APPENDIX B

ARGUMENTATION: CLAIMS AND EVIDENCE FORM

ARGUMENTATION: CLAIMS AND EVIDENCE Name _____

Question / Purpose:

Our Claim:

Our Evidence:

Our Justification of the Evidence:

Final statement or rule:

APPENDIX C
BALANCED EQUATION ARGUMENTATION

ARGUMENTATION: CLAIMS AND EVIDENCE Name _____

Question / Purpose:

Write and balance the following equation in the claim box. Use what you have learned to give evidence for your answer and a justification of the evidence. Your team will have to argue your answer.

Our Claim: Barium chloride reacts with potassium sulfate to produce potassium chloride and barium sulfate.

Our Evidence:

Our Justification of the Evidence:

Final statement or rule:

APPENDIX D
DECOMPOSITION OF WATER LAB

DECOMPOSITION OF WATER LAB

NAME _____

QUESTION: What is electrolysis? Which gas forms at which electrode during electrolysis? Explain how you know this.

SAFETY: Wear goggles at all times. You will also be generating electric current so be careful of not to shock yourself by touching the electrodes when you are generating current.

MATERIAL: Beaker Water Salt Wires with Alligator Clips
2 Pencil Leads Genco Hand Generator

PROCEDURES:

1. Plug the wires with the alligator clips into the Genco Hand Generator.
2. Clip each of the pencil leads to an alligator clip.
3. Fill the beaker $\frac{1}{2}$ full of water. Add a pinch of salt to the water.
4. One partner will hold the pencil leads in the water. Make sure that you are only touching the plastics on the wires.
5. The other partner will crank the hand generator.
6. Record all observations in a data table.

POST-LAB QUESTION:

1. Which electrode bubbles faster? Explain why.
2. Which gas is produced slower? Explain why.
3. Which is the anode (where negative ions are generated)?
4. Which is the cathode (where positive ions are generated)?
5. Write a balanced equation for the reaction.

APPENDIX E

GOLF BALL AND PING-PONG BALL DISCREPANT EVENT DEMONSTRATION

Name _____

GOLF BALL AND PING-PONG BALL DISCREPANT EVENT



Predict what will happen when
I drop the golf ball.



Predict what will happen when
I drop the Ping-Pong ball.



Predict what will happen when I
drop the two balls stacked on top
of each other.

Develop an argument for what is happening when the balls are dropped together. Include a claim, evidence, and the justification of your evidence. Discuss the observations that you made with your group and fill out the Argumentation worksheet. Design an additional inquiry activity to further test your argument.

APPENDIX F
RUSTY NAIL MISCONCEPTION PROBE

Name _____

THE RUSTY NAIL

There are four nails made of pure iron. The total mass of the four dry mails is recorded. All 4 nails are placed in an open dish with some water and exposed to the air for several weeks. After several weeks the nails are covered with rust. The nails are allowed to dry completely and then the total mass is taken again. None of the rust is lost during the weighing procedure.

What do you predict will happen to the mass of the nails? Circle your prediction and then provide an explanation describing your reason for your selection.

A. The mass of the dry, rusted nails will be more than the mass of the dry nails before they rusted.

B. The mass of the dry, rusted nails will be less than the mass of the dry nails before they rusted.

C. The mass of the dry, rusted nails will be the same as the mass of the dry nails before they rusted.



Describe the rule that you used to determine if the item was matter or not. Explain your answer clearly so that everyone can determine how you decided (Keeley, P., 2005).

APPENDIX G
THE MOLE LAB

THE MOLE

NAME _____

QUESTION: What does a mole of different substances look like?

SAFETY: Wear safety goggles at all times during the lab. Dispose of all chemicals according to the instructions of the teacher.

MATERIAL:

Balance
Sand

Pre 1982 Pennies
Baking Soda

Water

PROCEDURES:

1. Use the periodic table to determine the molar mass of Cu, H₂O, SiO₂, and NaHCO₃. That will give you grams per mole. Record that in a data table.
2. Measure out that amount of grams on the balance from the calculated amount in step 1.
3. Make observations about the amount of substance measured on the balance. Do this for each of the substances in step 1. Make sure that you record all observations in your data table.

POST-LAB QUESTION:

1. Which substance had the greatest amount to equal 1 mole?
2. Which substance had the smallest amount to equal 1 mole?
3. How many 500 mg aspirin tablets would it take to make a mole of aspirin (C₉H₈O₄)?
4. Which would be heavier a mole of sodium chloride or a mole of potassium chloride? Explain your answer.
5. Why can you not calculate the mass of a mole of most mixtures?
6. Be prepared to answer each of these questions in your argumentation.

APPENDIX H
CALCULATING MOLES LAB

CALCULATING MOLES LAB

NAME _____

QUESTION: How many moles are of sugar and salt are contained in a packet of salt or sugar?

SAFETY: Wear goggles at all times. Dispose of the sugar and salt in the trashcan.

MATERIAL:

2 salt packets

2 sugar packets

electronic balance

PROCEDURES:

1. Obtain a weigh paper and place it on the electronic balance and zero the scale. Pour the entire packet of sugar onto the weigh paper.
2. Record the mass in the data table. Collect data from 2 other groups, so that you have 3 data points. Record these in your data table as well.
3. Use the molar mass ($C_6H_{12}O_6$) to calculate the moles in a sugar packet.
4. Use all 3 moles calculated to determine an average number of moles.
5. Repeat these steps with the salt packets ($NaCl$).

POST-LAB QUESTION:

1. Which packet was bigger?
2. Which packet had more moles? Explain.
3. How many grams of sugar would it take to make the same number of moles as the salt. Be prepared to explain this in your argumentation.

APPENDIX I
GAS LAWS LAB

GAS LAWS LAB

NAME _____

QUESTION: How do different items react to changes in pressure? What gas law best relates to this activity?

SAFETY: Do not eat or drink during the lab. Wear goggles at all times. Clean up all spills and wash all lab equipment.

MATERIAL: Syringe Water Small Marshmallows Soda

PROCEDURES:

1. Fill the syringe half full of air. Place your finger over the end of the syringe and compress the air by pushing down on the plunger. How far were you able to push down on the air? (Use the measurements on the syringe and record the volumes.)
2. With the tip still covered pull out on the plunger. How far were you able to expand the air?
3. Fill the syringe half full of water and remove all air bubbles. Place your finger over the end of the syringe and push down on the plunger. How far were you able to compress the water? (Use the measurements on the syringe and record the volumes.)
4. Which is more compressible gasses or liquids?
5. Put one or two small marshmallows in the syringe that is half full of air and cover tip with your finger. What happens when you press down on the plunger? What happens when you pull on the plunger? (For best results you may need to replace your marshmallows between pushing and pulling on the plunger.) What does this tell you about marshmallows?
6. Fill the syringe half full of soda and cover the tip with your finger. What happens to the soda when you push down on the plunger? What happens to the soda when you pull on the plunger? Why does this happen to the soda?
7. Record all observation in a data table. Record all answers to the questions in a data table.
8. Use this information to complete the argumentation worksheet. Present an argument that answers the questions at the beginning of the lab.

APPENDIX J
CHEMISTRY ATTITUDINAL SURVEY

Chemistry Attitudinal Survey

Please circle the letter of the statement that best represents your view.
 Participation in this survey is voluntary. Choosing to participate or choosing to not participate in this survey will not affect your grade or class standing. Please circle your gender and the period you have chemistry. This survey is not standardized or validated.

- | | Male | Female | Period 2 | Period 3 |
|--|----------|-------------|----------------------|----------|
| 1. I enjoy my science class. | | | | |
| a. Strongly Agree | b. Agree | c. Disagree | d. Strongly Disagree | |
| 2. Doing labs is fun for me. | | | | |
| a. Strongly Agree | b. Agree | c. Disagree | d. Strongly Disagree | |
| 3. I learn science best through lecture and bookwork. | | | | |
| a. Strongly Agree | b. Agree | c. Disagree | d. Strongly Disagree | |
| 4. I learn science best through doing labs. | | | | |
| a. Strongly Agree | b. Agree | c. Disagree | d. Strongly Disagree | |
| 5. I understand the purpose of labs and how it relates to the material we are learning. | | | | |
| a. Strongly Agree | b. Agree | c. Disagree | d. Strongly Disagree | |
| 6. Questions that follow labs often help me to understand the scientific concepts of labs. | | | | |
| a. Strongly Agree | b. Agree | c. Disagree | d. Strongly Disagree | |
| 7. Writing conclusions is easy for me and I can explain what I have learned. | | | | |
| a. Strongly Agree | b. Agree | c. Disagree | d. Strongly Disagree | |
| 8. I participate more when I work in groups than when I work alone. | | | | |
| a. Strongly Agree | b. Agree | c. Disagree | d. Strongly Disagree | |
| 9. Listening to others helps me to understand the material better. | | | | |
| a. Strongly Agree | b. Agree | c. Disagree | d. Strongly Disagree | |
| 10. Solving problems is easier when I work in a group. | | | | |
| a. Strongly Agree | b. Agree | c. Disagree | d. Strongly Disagree | |
| 11. Hands-on activities make science more enjoyable. | | | | |
| a. Strongly Agree | b. Agree | c. Disagree | d. Strongly Disagree | |

Short Answer – please answer the following questions as completely as you can.

12. Why do teachers give labs in science class?

13. How well do labs help you to understand chemistry? Explain your answer.

14. Explain how working in the group motivated you or did not motivate you to learn the science concepts?

15. What is the hardest part about working with other people?

16. What was the best part about working with other people?

APPENDIX K

PRE-ARGUMENTATION INTERVIEW QUESTIONNAIRE

Pre-Argumentation Interview Questionnaire

NAME _____

Participation in this Interview Questionnaire is voluntary and will not lower your grade in any way.

1. What is the hardest part about writing laboratory conclusions?

2. When you are finished with the lab questions and conclusions do you feel like you have a better understanding of the material?

3. Do you like working in groups on labs or alone? Why?

4. If you could change anything about labs what would it be?

APPENDIX L

POST-ARGUMENTATION INTERVIEW QUESTIONNAIRE

Post-Argumentation Interview Questionnaire

NAME _____

Participation in this Interview Questionnaire is voluntary and will not lower your grade in any way.

1. What is the hardest part about writing laboratory conclusions?

2. When you are finished with the argumentation process do you feel like you have a better understanding of the material?

3. Do you like working in groups to develop an argument about what happened or alone? Why?

4. When you listened to all the other groups present their arguments did it help you improve your argument?

5. After the argumentation process is it easier to answer lab questions and write conclusions? Explain your answer.

APPENDIX M
INSTITUTIONAL REVIEW BOARD APPROVAL



INSTITUTIONAL REVIEW BOARD
For the Protection of Human Subjects
FWA 00000165

960 Technology Blvd. Room 127
c/o Immunology & Infectious Diseases
Montana State University
Bozeman, MT 59718
Telephone: 406-994-6783
FAX: 406-994-4303
E-mail: cherylj@montana.edu

Chair: Mark Quinn
406-994-5721
mquinn@montana.edu
Administrator:
Cheryl Johnson
406-994-6783
cherylj@montana.edu

MEMORANDUM

TO: Tracey Bidwell and Eric Brunsell
FROM: Mark Quinn, Chair *Mark Quinn et al*
DATE: November 16, 2015
RE: "Does Argument Driven Inquiry Help Students Understand the Concepts Being Reinforced During Laboratory Activities?" [TB111615-EX]

The above research, described in your submission of November 12, 2015, is exempt from the requirement of review by the Institutional Review Board in accordance with the Code of Federal regulations, Part 46, section 101. The specific paragraph which applies to your research is:

- ☒ (b) (1) Research conducted in established or commonly accepted educational settings, involving normal educational practices such as (i) research on regular and special education instructional strategies, or (ii) research on the effectiveness of or the comparison among instructional techniques, curricula, or classroom management methods.
- ☒ (b) (2) Research involving the use of educational tests (cognitive, diagnostic, aptitude, achievement), survey procedures, interview procedures or observation of public behavior, unless: (i) information obtained is recorded in such a manner that human subjects can be identified, directly or through identifiers linked to the subjects; and (ii) any disclosure of the human subjects' responses outside the research could reasonably place the subjects at risk of criminal or civil liability, or be damaging to the subjects' financial standing, employability, or reputation.
- ☐ (b) (3) Research involving the use of educational tests (cognitive, diagnostic, aptitude, achievement), survey procedures, interview procedures, or observation of public behavior that is not exempt under paragraph (b)(2) of this section, if: (i) the human subjects are elected or appointed public officials or candidates for public office; or (ii) federal statute(s) without exception that the confidentiality of the personally identifiable information will be maintained throughout the research and thereafter.
- ☐ (b) (4) Research involving the collection or study of existing data, documents, records, pathological specimens, or diagnostic specimens, if these sources are publicly available, or if the information is recorded by the investigator in such a manner that the subjects cannot be identified, directly or through identifiers linked to the subjects.
- ☐ (b) (5) Research and demonstration projects, which are conducted by or subject to the approval of department or agency heads, and which are designed to study, evaluate, or otherwise examine: (i) public benefit or service programs; (ii) procedures for obtaining benefits or services under those programs; (iii) possible changes in or alternatives to those programs or procedures; or (iv) possible changes in methods or levels of payment for benefits or services under those programs.
- ☐ (b) (6) Taste and food quality evaluation and consumer acceptance studies, (i) if wholesome foods without additives are consumed, or (ii) if a food is consumed that contains a food ingredient at or below the level and for a use found to be safe, or agricultural chemical or environmental contaminant at or below the level found to be safe, by the FDA, or approved by the EPA, or the Food Safety and Inspection Service of the USDA.

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