2010

The Efficacy of Chemistry Outreach Programs on Middle School Students

Erica M. Dumeyer
Western Kentucky University

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THE EFFICACY OF CHEMISTRY OUTREACH PROGRAMS ON MIDDLE SCHOOL STUDENTS

A Capstone Experience/Thesis Project

Presented in Partial Fulfillment of the Requirements for
the Degree Bachelor of Science with
Honors College Graduate Distinction at Western Kentucky University

By

Erica M. Dumeyer

****

Western Kentucky University
2010

CE/T Committee:

Dr. Lester Pesterfield, Advisor

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Mr. Nathan Phelps

Approved by

Advisor
Department of Chemistry
ABSTRACT

The current project was designed to determine if science outreach programs affect the attitude of the students toward science and increase the science content knowledge of the students participating in the program. Students from middle schools surrounding the Bowling Green area participated in the project. The data set includes a total of 850 students from 7th and 8th grade. Students were given a pre-test (taken several days before the presentation) and a post-test (taken several days after the presentation). The tests contain both subjective, affective as well as objective, content questions. The individual student pre-/post-tests were index numbered to protect the identity of the students. Each pre- and post-test was scored according to a defined rubric. The data was analyzed to determine if there was a statistical difference between scores on the pre- and post-tests. When a statistical difference was identified, the difference was then determined to be positive or negative employing the average difference in the values. The results from the various analyses are presented and discussed.

Keywords: Outreach, Chemistry, middle-school, statistical analysis
Dedicated to Alicia McDaniel for helping me keep my sanity throughout these four years at Western Kentucky University
ACKNOWLEDGEMENTS

This project would have never been made possible without the help from my Mom, Nancy Dumeyer, and my friends with the early stages of alphabetizing and indexing over 2,600 pages. I would like to thank my advisor, Dr. Lester Pesterfield, for having such a drive and love of helping the community through his outreach programs. I would also like to thank Dr. Stuart Burris for taking on the daunting task of devising the best method of indexing and inputting the data so that statistics would be relatively easy. In addition, I would like to extend a thank you to Mr. Nathan Phelps for being my third reader.
VITA

October 7, 1988..............................................................Born in Louisville, Kentucky

2006.................................................................Our Lady of Mercy Academy,
Louisville, Kentucky

FIELDS OF STUDY

Major Field: Biochemistry
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SECTION 1

INTRODUCTION

The current project was designed to determine if science outreach programs affect the attitude of the students toward science and increase the science content knowledge of the students participating in the program. Students from middle schools surrounding the Bowling Green area participated in the project. The data set includes a total of 850 students from 7th and 8th grade. The individual student pre-/post-tests were index numbered to protect the identity of the students.

The goal of the research is to determine if outreach programs improve students’ overall feelings toward science and determine if the students acquired any content knowledge. The outreach programs are meant to help teachers demonstrate to students the potential fun that science, chemistry in particular, has to offer. Previous studies have shown that outreach programs can be beneficial to both the school and the students involved (Mason, 2005). By having outreach programs, the students can observe and interact with demonstrations that would be difficult for many teachers to perform. Middle school teachers typically do not have the same access to chemicals and waste disposal as university faculty. This additional access allows the outreach program to present reactions to which students would not have otherwise been exposed. With the no-child
left behind program implemented in 2001, many of the teachers in middle school are teaching “out of discipline,” according to an editorial published in the Journal of Chemical Education. (Mason, 2005)

“Out of discipline” teaching is one of the major problems facing the education system and the reason outreach programs can be extremely beneficial and should be utilized. In one study, the participation in an outreach program was not only beneficial to the middle school students participating in it but also to the college students participating in teaching it. The study took second-quarter Introductory Chemistry students and had them assist in teaching chemistry in grades 4-6. The teachers of grades 4-6 believed that the interaction with the college students allowed the children to “produce projects that the students were proud of because of the guidance from the college students.” (Esson & Stevens-Truss, 2005)

The current project is designed to compare the results of a pre-test (taken several days before the presentation) and a post-test (taken several days after the presentation). The tests contain both subjective, affective as well as objective, content questions. The affective questions are used to gauge the interest of the student in science as a subject and as a career. The content questions cover topics that were presented during the outreach presentation. The specific topics addressed in the presentation and questions on the pre- and post-test were derived from the “Core Requirements for Science” from the Kentucky Department of Education website for middle school. These requirements are outlined in Figure 1.1 and Figure 1.2.

Each pre- and post-test was scored according to a defined rubric. The scoring of
Figure 1.1 – The first half of the core requirements of 6th-8th grade Physical Science Curriculum. (Kentucky Department of Education, 2006)

<table>
<thead>
<tr>
<th>Structure and Transformation of Matter</th>
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<tr>
<td>A basic understanding of matter is essential to the conceptual development of other big ideas in science. In the elementary years of conceptual development, students will be studying properties of matter and physical changes of matter at the macro level through direct observations, forming the foundation for subsequent learning. During the middle years, physical and chemical changes in matter are observed, and students begin to relate these changes to the smaller constituents of matter—namely, atoms and molecules. By high school, students will be dealing with evidence from both direct and indirect observations (microscopic level and smaller) to consider theories related to change and conservation of matter. The use of models (and an understanding of their scales and limitations) is an effective means of learning about the structure of matter. Looking for patterns in properties is also critical to comparing and explaining differences in matter.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>6th Grade</th>
<th>7th Grade</th>
<th>8th Grade</th>
</tr>
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<tbody>
<tr>
<td><strong>Physical Science</strong></td>
<td><strong>Physical Science</strong></td>
<td><strong>Physical Science</strong></td>
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| SC-M6 1.1.1 Students will explain how or why mixtures can be separated using physical properties. | SC-07-1.1.1 Students will:  
- classify substances according to their chemical/reactive properties;  
- infer real life applications for substances based on chemical/reactive properties.  |
| A mixture of substances often can be separated into the original substances by using one or more of its characteristic physical properties. DOK 2 | In chemical reactions, the total mass is conserved. Substances are often classified into groups if they react in similar ways. The patterns, which allow classification, can be used to infer or understand real life applications for those substances. DOK 3 | SC-08-1.1.1 Students will:  
- interpret models/representations of elements;  
- classify elements based upon patterns in their physical (e.g., density, boiling point, solubility) and chemical (e.g., flammability, reactivity) properties.  |
<p>| Models enhance understanding that an element is composed of a single type of atom. Organization/interpretation of data illustrates that when elements are listed according to the number of protons, repeating patterns of physical (e.g., density, boiling point, solubility) and chemical properties (e.g., flammability, reactivity), can be used to identify families of elements with similar properties. DOK2 |</p>
<table>
<thead>
<tr>
<th>SC-06-1.1.2</th>
<th>SC-07-1.1.2</th>
<th>SC-08-1.1.2</th>
</tr>
</thead>
</table>
| Students will identify and describe evidence of chemical and physical changes in matter. | Students will:  
- classify elements and compounds according to their properties;  
- compare properties of different combinations of elements. | Students will understand that matter is made of minute particles called atoms, and atoms are composed of even smaller components. The components of an atom have measurable properties such as mass and electrical charge. Each atom has a positively charged nucleus surrounded by negatively charged electrons. The electric force between the nucleus and the electrons holds the atom together. |
| In chemical reactions, the total mass is conserved. Substances are often classified into groups if they react in similar ways. The patterns that allow classification can be used to infer or understand real life applications for those substances. | Observations of simple experiments illustrate that the atoms of chemical elements do not break down during normal laboratory reactions such as heating, exposure to electric currents, or reaction with acids. Elements combine in many ways to produce compounds. Common patterns emerge when comparing and contrasting the properties of compounds to the elements from which they are made. Understanding of these patterns allows for evidence-based predictions of new or different combinations of elements/compounds. | Students will understand that the atom’s nucleus is composed of protons and neutrons that are much more massive than electrons. |
| DOK 2 | DOK 2 | DOK 2 |
the questions is discussed further in section 3. The data was analyzed to determine if there was a statistical difference between scores on the pre- and post-tests. When a statistical difference was identified, the difference was then determined to be positive or negative employing the average difference in the values.
SECTION 2

THE OUTREACH PRESENTATION

The outreach presentation lasts around 40-45 minutes and covers a defined range of topics. Throughout the presentation, the students are asked questions concerning the material presented to reinforce specific concepts. The presentation covers several topics, including chemical vs. physical changes, rates of reactions, energy changes during chemical reactions, reactivity trends of the elements, the reversibility of reactions, and the transformation of chemical energy into other forms of energy.

The presentation begins with an introduction to and explanation of chemical changes and how they differ from physical changes. In addition, the children are asked to identify the types of observations that could be made which would indicate a chemical versus physical changes. The second topic addressed is reaction kinetics. Both a rapid and slow reaction are shown. The first reaction is that of iron(III) chloride and ammonium thiocyanate. Iron(III) chloride is a translucent, yellow liquid and is presented to the students in a test tube. When ammonium thiocyanate, a colorless liquid, is added, the solution turns a blood red color. The children are asked what the color change indicates to reinforce concepts of a chemical change. The topic of slow chemical reactions is then introduced. The slow chemical reaction example is the synthesis of
polyurethane foam, by mixing a polyalcohol and diisocyanate. Once the two chemicals are mixed, they form a foam in the shape of a mushroom that hardens after a few minutes. When these two chemicals are put into the container together they do not start to react immediately, indicating a slow reaction. Even the reaction following the mixing of the two chemicals is not rapid. The container is passed around to the students because not only is this an example of a slow reaction, it is also an example of an exothermic reaction. This dual purpose reaction is a great transition into the next topic: thermodynamics.

Thermodynamics is the study of whether heat energy is released or absorbed during a chemical reaction. Exothermic reactions release heat energy and have an accompanying rise in temperature during the reaction. Endothermic reactions absorb heat energy and have a corresponding decrease in temperature. Both reaction types are demonstrated. The endothermic reaction is the same as that found in instant ice packs, which allows the students to see everyday uses for chemistry. Small pellets of ammonium nitrate are dissolved in water to form ammonium ions and nitrate ions. The reaction absorbs heat from its surroundings and causes the temperature of the beaker to drop. The beaker is passed around so the students can experience the extent of the resulting temperature change associated with the reaction first hand. The exothermic reaction is demonstrated using thermite sticks, which are composed of powdered aluminum metal and powdered iron(III) oxide. Once the thermite stick is lit, brightly colored sparks are produced along with droplets of molten aluminum oxide and elemental iron. The fact that
When the stick is submerged, the water instantaneously boils.

The next topic covered is the Periodic Table and the reactivity of the elements within a group on the Periodic Table. The children are first asked what they know about the Periodic Table referring to the breakdown of the table into three groups: metals, non-metals, and metalloids. The students are asked to discuss the properties of metals which usually include these answers; shiny, hard, valuable, conductive of heat and electricity, and used to make objects. The relative reactivity of four metals are demonstrated: sodium (Na), magnesium (Mg), potassium (K), and calcium (Ca). The Periodic Table is arranged so that the general reactivity of the metal increases moving down the column. The first metal discussed is sodium (Na).

Sodium is presented to the children in its elemental form. Na is a Group 1 metal and the elemental form appears as a grey and shiny solid. A small piece of Na metal is dropped into a beaker of water containing the pH indicator, phenolphthalein. This indicator allows the children to see the rapid change in pH which accompanies the reaction (in a basic environment phenolphthalein turns a bright pink color). Upon touching water the Na sparks, fizzes and moves around the surface of the water. The hydroxide generated during the reaction causes the color to change from colorless to bright pink. The reaction is written on the board for the students to see.

$$2Na(s) + 2H_2O(l) \rightarrow 2Na^+(aq) + 2OH^-(aq) + H_2(g)$$
They are asked to hypothesize if Na reacts that way, what will its neighbor magnesium do.

Magnesium is then shown in its elemental form. Magnesium is a Group 2 metal located directly to the right of Na. When Mg is placed in water, there is no visible reaction. This demonstrates the property of the Periodic Table that metals are grouped based on their reactivity which increases down the column. The reaction of Mg and water is written on the board under the reaction for Na\(_{(s)}\) with water.

\[
\text{Mg}\,_{(s)} + \text{H}_2\text{O}\,_{(l)} \rightarrow \text{no reaction}
\]

The students are asked to hypothesize what will happen if potassium is reacted with water. Potassium is a Group 1 metal. It is located below Na in the Periodic Table and therefore has a greater reactivity to water than Na. When K reacts with water, it produces a bright, purple flame, fizzes and changes the color of the water to pink (due to the indicator). The reaction for K\(_{(s)}\) and water is written underneath the equation for Mg\(_{(s)}\) reacting with water.

\[
2\text{K}\,_{(s)} + 2\text{H}_2\text{O} \rightarrow 2\text{K}^{+}\,_{(aq)} + 2\text{OH}^-\,_{(aq)} + \text{H}_2\,_{(g)}
\]
The students observe that $K_{(s)}$ has a greater reactivity to water than $Na_{(s)}$. Additionally the presenter relates that if cesium metal is exposed to air, it will burst into flames. Students are then asked to describe the trend in reactivity for metals moving down a group.

The last metal is calcium (Ca). It is located under Mg on the Periodic Table. Calcium is dropped into a beaker of water and phenolphthalein. The solid calcium sits at the bottom of the beaker nonreactive for 15-20 seconds. Then it begins to fizz and turns the water turns from colorless to pink. This demonstrates that even though Mg is non-reactive, Ca is reactive just at a slower pace. This reinforces the idea that properties increase down a column. The chemical reaction is written on the board.

$$Ca_{(s)} + 2H_2O_{(l)} \rightarrow Ca + 2OH^{-}_{(aq)} + H_2_{(g)}$$

A common question following the conclusion of this set of reactions is concerning the color change from colorless to pink. The students are usually able to infer that there must be a common product in all of the reactions. By looking at the reactions written on the board, the students see that a common product is the $OH^{-}$ anion. The reaction of the $OH^{-}$ with the indicator is why the water turns a bright pink color.
A subject also discussed at this time is the chemical nature/identity of elements in various food products. Many students are aware that calcium is present in dairy products, as well as sodium in table salt, and potassium in bananas. From the reactions, the students have observed that when Na is added to water a rapid reaction occurs and that when K is added to water a violent reaction occurs. However, the students know that the ingestion of calcium, sodium, and potassium in food products does not lead to violent reactions in the body. This apparent contradiction allows the presenter to introduce the concepts of cations (positively charged ions) and anions (negatively charged ions) and to clarify that cations and anions are consumed in food products not the neutral, elemental forms used in the demonstrated reactions.

The last topic covered is the transformation of chemical energy to other forms of energy. A balloon filled with \( H_2(g) \) and \( O_2(g) \) is ignited over a candle placed in the front of the classroom. The reaction is as follows:

\[
2H_2(g) + O_2(g) \rightarrow 2H_2O(g)
\]

One of the first things covered concerning this reaction is safety and the proper use of safety equipment. This is because the reaction produces a fireball approximately 3 feet in diameter. Students are instructed on how to protect their hearing from the noise produced by the reaction. Once the safety precautions are covered, the reaction is demonstrated. Through discussion, the children conclude that chemical energy is transformed into four types of energy by this reaction: sound, light, thermal/heat, and kinetic, indicated by the loud noise, the fireball, the heat, and the motion of the balloon across the room.
respectively. A real world application which always peaks the students’ interest is that the reaction is used to help launch the space shuttle.
The pre-tests and post-tests were graded according to an established rubric and the scores were entered into Microsoft Excel workbooks. The data was separated by school and grade level. The entire data set includes 850 students from four schools. The affective questions (labeled AQ1-AQ3) probed whether or not students found science interesting, whether or not they enjoyed studying science, and whether or not they would consider a career in the science or medical field. Students marked their responses on a Likert scale with 1 being strongly disagree and 5 being strongly agree. The objective, content questions (labeled CQ1-CQ6) tested whether the students acquired any content knowledge covered during the presentation. Students were asked about ions, thermochemistry, the use of chemical compounds in everyday life, the classification of changes as chemical or physical, and forms of energy. Each questions point value was assigned based on the difficulty level as indicated in Table 3.1. The average score for each question on the pre-test and post-test is given in Table 3.2.

<table>
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<tr>
<th>Point Values for Content Questions</th>
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<tbody>
<tr>
<td>CQ1</td>
</tr>
<tr>
<td>0-1</td>
</tr>
</tbody>
</table>

*Table 3.1: Available point values for each content question*
The first affective question (referred to as AQ1) stated, “I find science interesting.” The second affective question (referred to as AQ2) stated, “I enjoy studying science.” The third affective question (referred to as AQ3) stated, “I would consider a career in science or a medical field.” As indicated above these questions were scored on a Likert scale from 1-5.

The second set of questions tested the students on the content material covered in the presentation. These questions were graded based on their difficulty. While the same content was tested the questions on the pre-test and post-test were not identical.

The first content question (referred to as CQ1) tested the students over the definition of cations and anions. The students received 1 point for the correct answer. The pre-test question stated, “a negatively charged ion is called a/an” while the post-test questions stated, “a positively charged ion is called a/an.” The answers are anion and cation respectively. This topic was covered in the presentation when discussing the reactivity of metals and the ions they form. Also this topic was reinforced when discussing the daily ingestion of Na\(^+\), Ca\(^{2+}\), and K\(^+\); as opposed to Na, Ca, K.

The second content question (referred to as CQ2) tested the students over the thermodynamics of reactions. The students received one point for the correct answer. The pre-test question stated, “a chemical reaction that absorbs heat is called” while the post-test questions stated, “a chemical reaction that releases heat is called.” The answers are endothermic and exothermic respectively. The topic was covered in the presentation when discussing the thermodynamics of reactions that included the reactions that takes place inside ice packs and the igniting of a thermite stick.
The third content question (referred to as CQ3) tested the students over the use of chemical compounds in everyday life. The students received 1, 2, or 3 points based on their answer. If they gave a chemical compound and a use, they received 3 points. If they used another name for the chemical compound (i.e. “great stuff” is brand name for the polyurethane foam used in caulkking) and gave a use, they received 2 points. If they just gave the name of a chemical compound and no use, they received one point. The pre-test and post-test question stated, “Name a chemical compound and tell how it is used in everyday life”. The answers to this question can be very diverse. There were many examples in the presentation over this topic. Some included the reaction that takes place in ice packs, table salt, CO₂ used for carbonation, the polyurethane foam used to caulk appliances, etc.

The fourth content question (referred to as CQ4) tested the students over the reactivity of elements in relation to their position on the Periodic Table. The students received 8, 4, or 0 points on the pre-test and 8, 6, 4, 2, or 0 points on the post-test. On the pre-test the students were given an example set of equations and reaction descriptions in which the reactivity decreased moving down the column on the Periodic Table. From the examples, the students were required to predict the reactivity of an element even lower in the column. They received 8 point for saying no reaction, 4 for saying a slow reaction, and 0 for saying a rapid reaction or an explosion. The post-test gave the students an example set of equations and reaction descriptions in which the reactivity increased moving down the column on the Periodic Table. From the examples, the students were required to predict the reactivity of an element even lower in the column. The topic of
reactivity was covered in the presentation when Na, K, Mg, and Ca were reacted with water. The students received 8 points for stating there was a rapid chemical reaction that produced a bright purple/pink flame. They received 6 points for stating there was a reaction (not stating that it was rapid) and the presence of a bright pink/purple flame. The student received 4 points if they stated that the reaction was rapid but failed to describe the flame color. The student received 2 points if they either described the flame color or said that there was a reaction. If they did not state any of the above combinations, then they received no credit.

The fifth content question (referred to as CQ5) asked students to classify changes as physical or chemical. The students received 0-6 points based on the number of changes they classified correctly. The pre-test asked them to circle all of the observations that describe physical changes. If they did not circle any, they received zero. The physical changes included answers B, C, and F. Please refer to the appendices A and B for a copy of the pre- and post-test. The post-test asked for chemical changes and included answers A, D, and E. If a student only circle A, D, and E on the post-test, they received full credit. If they circled A, D, E, and one of the physical changes, than they received 5 points, etc.

Making observations and identifying chemical changes are the first topics covered in the presentation.

The last, sixth content question (referred to as CQ6) tested the students over forms of energy. The students received 0-5 points based on how many they circled correctly.

Both the pre-test and the post-test asked them to “circle all which are kinds of energy”. If they did not circle any, they received zero. If they circled the three correct answers, they
received 5 points. If they circled an additional answer or did not circle one of the correct answers, they received 4 points, etc. The students were taught forms of energy all throughout the presentation. They experienced sound energy with the exploding balloon, light with the igniting of the thermite sticks as well as the reactions involving K. They also were shown kinetic/mechanical with the propulsion of the balloon across the room following the reaction and chemical with almost every reaction demonstrated.

<table>
<thead>
<tr>
<th>Question</th>
<th>Overall pre-test</th>
<th>Overall post-test</th>
<th>Male pre-test</th>
<th>Male post-test</th>
<th>Female pre-test</th>
<th>Female post-test</th>
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<tr>
<td>AQ2</td>
<td>3.130</td>
<td>3.300</td>
<td>3.146</td>
<td>3.302</td>
<td>3.119</td>
<td>3.326</td>
</tr>
<tr>
<td>AQ3</td>
<td>2.834</td>
<td>3.010</td>
<td>2.649</td>
<td>2.859</td>
<td>3.009</td>
<td>3.148</td>
</tr>
<tr>
<td>CQ1</td>
<td>0.025</td>
<td>0.202</td>
<td>0.005</td>
<td>0.213</td>
<td>0.044</td>
<td>0.196</td>
</tr>
<tr>
<td>CQ2</td>
<td>0.148</td>
<td>0.418</td>
<td>0.126</td>
<td>0.418</td>
<td>0.165</td>
<td>0.420</td>
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<tr>
<td>CQ3</td>
<td>1.261</td>
<td>1.590</td>
<td>1.196</td>
<td>1.468</td>
<td>1.335</td>
<td>1.719</td>
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<tr>
<td>CQ4</td>
<td>0.845</td>
<td>1.767</td>
<td>0.782</td>
<td>1.554</td>
<td>0.931</td>
<td>2.014</td>
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<tr>
<td>CQ5</td>
<td>3.440</td>
<td>3.924</td>
<td>3.436</td>
<td>3.817</td>
<td>3.461</td>
<td>4.048</td>
</tr>
</tbody>
</table>

Table 3.2: Average pre-test and post-test scores for each question in each data set

A heteroscedastic or homoscedastic t-test averages the data set and determines whether there is a difference between scores, whereas a paired t-test determines whether individuals within the data set have a statistical difference in their scores. The results of the t-test for the entire data set of 850 students were encouraging with probability values of 0.9 or higher, refer to Table 3.3. The average difference between the pre- and post-test questions for all data sets and subsets showed improvement in the scores.
The entire data set was separated by gender into males and females. There were 404 males in the data set and 438 females in the data set. Eight individuals did not indicate gender on either the pre-test or post-test. Analysis of the male subset data showed a statistically significant difference in the score on every question. The p-values of over 0.9 paired with the positive average differences suggests improvement was made on every question. Similar results were also found for the female subset data, except CQ6, which deals with forms of energy. The average female score on CQ6 on the pre-test was 3.65 and 3.71 on the post-test. While there is improvement, the probability level is not high enough to be considered significant. The results of the t-test as well as the average difference between the pre- and post-test for each question are given in Table 3.4 for the male and female subsets.

<table>
<thead>
<tr>
<th>Question</th>
<th>AQ1</th>
<th>AQ2</th>
<th>AQ3</th>
<th>CQ1</th>
<th>CQ2</th>
<th>CQ3</th>
<th>CQ4</th>
<th>CQ5</th>
<th>CQ6</th>
</tr>
</thead>
<tbody>
<tr>
<td>p-value</td>
<td>1.000</td>
<td>0.999</td>
<td>0.998</td>
<td>1.000</td>
<td>1.000</td>
<td>1.000</td>
<td>1.000</td>
<td>1.000</td>
<td>0.939</td>
</tr>
</tbody>
</table>

Table 3.3: T-test significance levels for the pre-test to post-test comparison (n = 850). p > 0.900 indicates a significant difference between the two data sets.

<table>
<thead>
<tr>
<th></th>
<th>n</th>
<th>AQ1</th>
<th>AQ2</th>
<th>AQ3</th>
<th>CQ1</th>
<th>CQ2</th>
<th>CQ3</th>
<th>CQ4</th>
<th>CQ5</th>
<th>CQ6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Males</td>
<td>404</td>
<td>.999</td>
<td>.979</td>
<td>.992</td>
<td>1.000</td>
<td>1.000</td>
<td>.997</td>
<td>1.000</td>
<td>1.000</td>
<td>.966</td>
</tr>
<tr>
<td>Females</td>
<td>438</td>
<td>.997</td>
<td>.998</td>
<td>.943</td>
<td>1.000</td>
<td>1.000</td>
<td>1.000</td>
<td>1.000</td>
<td>1.000</td>
<td>.746</td>
</tr>
<tr>
<td>Average difference from pre-test–post-test</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Males</td>
<td>404</td>
<td>0.237</td>
<td>0.159</td>
<td>0.215</td>
<td>0.005</td>
<td>0.127</td>
<td>1.188</td>
<td>0.771</td>
<td>3.432</td>
<td>3.583</td>
</tr>
<tr>
<td>Females</td>
<td>438</td>
<td>0.189</td>
<td>0.205</td>
<td>0.139</td>
<td>0.043</td>
<td>0.164</td>
<td>1.329</td>
<td>0.936</td>
<td>3.450</td>
<td>3.658</td>
</tr>
</tbody>
</table>

Table 3.4: T-test significance levels for the pre-test to post-test comparison for separate gender groups and average difference values for both groups. p > 0.900 indicates a significant difference.
A paired t-test was also performed on the entire data set and the gender subsets. The p-values from the paired t-test showed a significant difference in the score on every question, except the female subset on CQ6. The p-values of over 0.900 paired with the positive average differences suggest improvement was made on every question. These results are given in Table 3.5.

<table>
<thead>
<tr>
<th>Data Set</th>
<th>AF1</th>
<th>AF2</th>
<th>AF3</th>
<th>CQ1</th>
<th>CQ2</th>
<th>CQ3</th>
<th>CQ4</th>
<th>CQ5</th>
<th>CQ6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Full</td>
<td>1.000</td>
<td>1.000</td>
<td>1.000</td>
<td>1.000</td>
<td>1.000</td>
<td>1.000</td>
<td>1.000</td>
<td>1.000</td>
<td>0.963</td>
</tr>
<tr>
<td>Males</td>
<td>1.000</td>
<td>1.000</td>
<td>1.000</td>
<td>1.000</td>
<td>1.000</td>
<td>1.000</td>
<td>1.000</td>
<td>1.000</td>
<td>0.984</td>
</tr>
<tr>
<td>Females</td>
<td>1.000</td>
<td>1.000</td>
<td>0.999</td>
<td>1.000</td>
<td>1.000</td>
<td>1.000</td>
<td>1.000</td>
<td>1.000</td>
<td>0.778</td>
</tr>
</tbody>
</table>

*Table 3.5: Paired t-test significance levels for the pre-test to post-test comparison. p > 0.900 indicates a significant difference.*

Overall, there was improvement in the scores of every question by each data set except for CQ6 in the female data set. Even though there is a positive difference in the averages from the pre-test and post-test for CQ6 paired with the results from the t-test there can be no inference that the female students overall learned more about different forms of energy than they knew before the presentation.
SECTION 4

CONCLUSION AND FUTURE WORK

A clear improvement is seen from pre-test to post-test for the overall data set of 850 students and for the gender specific subsets. Significance values of over 0.900 for the t-tests showed average improvement by the groups within the data sets, excluding the females on CQ6. Similarly, the significance values of over 0.900 for the paired t-tests showed a significant difference in the scores of the individuals, paired with the positive average differences of the group indicate an improvement by individuals, excluding females on CQ6. This indicates that outreach programs do help to improve the learning of the material as well as the attitude of students toward science. From the analysis it can be concluded that outreach programs are beneficial to middle school students and encourage them towards a greater interest in science. Additionally outreach programs allow students to have experiences in science to which they would otherwise not be exposed.

The low scores on CQ1 (identifying ions) and CQ4 (predicting the reactivity of elements on the Periodic Table) suggests that either the concepts need to be presented in more detail or the questions need to be rewritten. In addition, the female data set did not show significant improvement in the forms of energy question. The cause of this is unclear at this time, but warrants further investigation. It would also be important to test
more schools to increase the number of subjects in all of the data sets to test whether this trend continues.

From observed trends in student answers for the content questions on the pre- and post-tests, revision of the questions could be beneficial for better probing of the students’ content knowledge. Suggested revisions of the pre- and post-tests are presented in Appendix C and D respectively. The affective questions have not been changed. CQ1 was modified on both the pre-test and the post-test. On the original tests, the questions were “a negatively charged ion is called a/an” and “a positively charged ion is called a/an”. Many students missed the points available from this question because they answered with ”electron” and ”proton”. In the revised test the pre-test question is, ”Atoms are made of charged particles called protons and electrons. An atom with fewer electrons is positively charged and called a/an:” The revised post-test question is, “Atoms are made of charged particles called protons and electrons. An atom with more electrons is negatively charged and called a/an:” The answers for both the original and modified CQ1 are identical. This is so the grading would remain constant. It is anticipated that these modifications will better clarify for the students the content material being tested.

CQ2 was also modified by adding the phrases “and the surroundings have a corresponding decrease in temperature is called:” and “and the surroundings have a corresponding increase in temperature is called:” were added to the endothermic/exothermic question on the pre-test and post-test respectively. The answers do not change to retain the grading rubric.
CQ3 was not modified significantly. The “and” in the middle of the question was capitalized to emphasize a chemical compound and a use in daily life are needed for full points. This modification was made because on many pre-/post-tests students only responded with a chemical compound and not its use in daily life. This modification should draw students’ attention to the fact that two pieces of information are required to answer the question.

CQ4 was significantly modified. The scores on CQ4 were the lowest of both the pre- and post-tests. The low scores could be attributed to the fact that many of the students are probably unaware of the extent of detail needed to earn full credit. To clarify the level of detail required to fully answer the question the following changes were made. On the revised pre-test the students are instructed to choose and circle one of the following that best describes the reaction rate: “fast, explosive”, “slow”, or “no reaction”. On the revised post-test the students are similarly instructed to circle one of the following that best describes the reaction, however, they circle both the reaction rate as well as a flame description. The choices for reaction rate are “fast, explosive”, “slow”, or “no reaction”, and for flame, “purple flame”, “blue flame”, “no flame”. It is anticipated these modifications will allow students to better understand the extent of description necessary to answer the question.

CQ5 was not modified very significantly. Some students did not select all the possible correct answers, but only circled one correct answer. To encourage student to select all possible answers letters preceding the descriptive statements were changed to
check boxes. Additionally the word all in the question was capitalized. This should encourage students to read the entire question and all of the descriptive statements.

CQ6 was slightly modified. The word all in the question “Circle all which are kinds (forms) of energy” was capitalized. This should encourage students to circle all the types of energy.

The changes made to these questions should afford the students a better opportunity to answer the questions without confusion and better allow the researchers to probe the students’ content knowledge.

To expand the scope of this project three additional areas could be utilized. First, presentations need to be made at more schools so the number of test subjects could be increased and the data set expanded. Second, a follow-up study to probe whether students have long-term retention of content knowledge and positive attitudes towards science should be conducted. Third, after the initial presentation has been made an additional classroom visit incorporating a hands-on-activity could be conducted to explore the effect of multiple outreach activities on enhancing students’ attitudes towards science and improving their retention of content knowledge.
Literature Cited


Appendix A
PRE-TEST

First Initial: _____ Middle Initial: _____ First Four Letters of Last Name: 

Gender: Male  Female  Grade:  6  7  8  9  School: ________________________________

Circle the response which best describes you.

I find science interesting. Strongly Disagree Neutral Agree Strongly Agree
I enjoy studying science. Strongly Disagree Neutral Agree Strongly Agree
I would consider a career in science or a medical field. Strongly Disagree Neutral Agree Strongly Agree

Answer the following questions to the best of your ability.

1. A negatively charged ion is called a/an: ________________________________

2. A chemical reaction that absorbs heat is called: ________________________________

3. Name a chemical compound and tell how it is used in daily life. ________________________________

4. F₂, Cl₂, Br₂ and I₂ are known as the halogens and are found in Group 17 (VIIA) on the periodic table. A student makes the following observations when F₂ and Cl₂ are reacted with NO.

<table>
<thead>
<tr>
<th>Reaction</th>
<th>Observation</th>
</tr>
</thead>
<tbody>
<tr>
<td>F₂ + 2 NO → 2 NOF</td>
<td>Reaction is very rapid, almost explosive in nature.</td>
</tr>
<tr>
<td>Cl₂ + 2 NO → 2 NOCl</td>
<td>Reaction is slow with only slight bubbling.</td>
</tr>
</tbody>
</table>

   What do you think would happen if Br₂ was reacted with NO?

5. Circle the letter for all the observations that describe a physical change.

   a) Nickel metal is mixed with nitric acid to form a green solution and a reddish-brown gas.
   b) A solution of sodium chloride is evaporated to dryness leaving solid sodium chloride.
   c) Solid carbon dioxide is sublimated to form a gas.
   d) Ammonia is added to a copper sulfate solution to form a dark blue solid.
   e) Paper is burned in air.
   f) A piece of silver is hammered into a thin sheet.

6. Circle all which are kinds (forms) of energy.

   mechanical  color  chemical  precipitation  heat

25
Appendix B
POST-TEST

First Initial: _______ Middle Initial: _______ First Four Letters of Last Name: _______

Gender: Male Female Grade: 6 7 8 9 School: ________________________________

Circle the response which best describes you.

I find science interesting. Strongly Disagree Neutral Agree Strongly Agree

I enjoy studying science. Strongly Disagree Neutral Agree Strongly Agree

I would consider a career in science or a medical field. Strongly Disagree Neutral Agree Strongly Agree

Answer the following questions to the best of your ability.

1. A positively charged ion is called a/an: ________________________________

2. A chemical reaction that releases heat is called: ________________________________

3. Name a chemical compound and tell how it is used in daily life.

4. Li, Na, K, Rb and Cs are known as the alkali metals and are found in Group 1 (IA) on the periodic table. A student makes the following observations when K and Rb are reacted with O₂.

<table>
<thead>
<tr>
<th>Reaction</th>
<th>Observation</th>
</tr>
</thead>
<tbody>
<tr>
<td>4 K + O₂ → 2 K₂O</td>
<td>Reaction is slow with a faint purple flame color.</td>
</tr>
<tr>
<td>4 Rb + O₂ → 2 Rb₂O</td>
<td>Reaction is rapid with bright lavender flame color.</td>
</tr>
</tbody>
</table>

What do you think would happen if Cs is reacted with O₂?

5. Circle the letter for all the observations that describe a physical change.

a) Hydrochloric acid is poured over copper metal to produce a greenish-yellow solution.
b) A sample of sodium chloride is dissolved in water.
c) Liquid water is frozen to form a solid.
d) Ammonia is added to a copper sulfate solution to form a dark blue solid.
e) Wood is burned in air.
f) A piece of aluminum is drawn into a thin wire.

6. Circle all which are kinds (forms) of energy.

sound color chemical dissolution light

26
Appendix C
REVISED PRE-TEST

First Initial: _____  Middle Initial: _____  First Four Letters of Last Name: 

Gender: Male  Female  Grade: 6  7  8  9  School: ___________________________

Circle the response which best describes you.

I find science interesting.  Strongly Disagree  Neutral  Agree  Strongly Agree

I enjoy studying science.  Strongly Disagree  Neutral  Agree  Strongly Agree

I would consider a career in science or a medical field.  Strongly Disagree  Neutral  Agree  Strongly Agree

Answer the following questions to the best of your ability.

7. A negatively charged ion is called a/an:

8. A chemical reaction that absorbs heat is called:

9. Name a chemical compound and tell how it is used in daily life.

10. F₂, Cl₂, Br₂ and I₂ are known as the halogens and are found in Group 17 (VIIA) on the periodic table.

   A student makes the following observations when F₂ and Cl₂ are reacted with NO.

<table>
<thead>
<tr>
<th>Reaction</th>
<th>Observation</th>
</tr>
</thead>
<tbody>
<tr>
<td>F₂ + 2 NO → 2 NOF</td>
<td>Reaction is very rapid, almost explosive in nature.</td>
</tr>
<tr>
<td>Cl₂ + 2 NO → 2 NOCl</td>
<td>Reaction is slow with only slight bubbling.</td>
</tr>
</tbody>
</table>

   What do you think would happen if Br₂ was reacted with NO?

11. Circle the letter for all the observations that describe a physical change.

   - Nickel metal is mixed with nitric acid to form a green solution and a reddish-brown gas.
   - A solution of sodium chloride is evaporated to dryness leaving solid sodium chloride.
   - Solid carbon dioxide is sublimated to form a gas.
   - Ammonia is added to a copper sulfate solution to form a dark blue solid.
   - Paper is burned in air.
   - A piece of silver is hammered into a thin sheet.

12. Circle all which are kinds (forms) of energy.

   mechanical  color  chemical  precipitation  heat
Appendix D
REVISED POST-TEST

First Initial: _______ Middle Initial: _______ First Four Letters of Last Name: _______

Gender: Male  Female  Grade: 6 7 8 9  School: ________________________________

Circle the response which best describes you.

I find science interesting.  Strongly Disagree Neutral Agree  Strongly Agree
Disagree

I enjoy studying science.  Strongly Disagree Neutral Agree  Strongly Agree
Disagree

I would consider a career in science or a medical field.  Strongly Disagree Neutral Agree  Strongly Agree
Disagree

Answer the following questions to the best of your ability.

7. A positively charged ion is called a/an:\n
8. A chemical reaction that releases heat is called:\n
9. Name a chemical compound and tell how it is used in daily life.

10. Li, Na, K, Rb and Cs are known as the alkali metals and are found in Group 1 (IA) on the periodic table. A student makes the following observations when K and Rb are reacted with O_2.

<table>
<thead>
<tr>
<th>Reaction</th>
<th>Observation</th>
</tr>
</thead>
<tbody>
<tr>
<td>4 K + O_2 → 2 K_2O</td>
<td>Reaction is slow with a faint purple flame color.</td>
</tr>
<tr>
<td>4 Rb + O_2 → 2 Rb_2O</td>
<td>Reaction is rapid with bright lavender flame color.</td>
</tr>
</tbody>
</table>

What do you think would happen if Cs is reacted with O_2?

11. Circle the letter for all the observations that describe a physical change.

- Hydrochloric acid is poured over copper metal to produce a greenish-yellow solution.
- A sample of sodium chloride is dissolved in water.
- Liquid water is frozen to form a solid.
- Ammonia is added to a copper sulfate solution to form a dark blue solid.
- Wood is burned in air.
- A piece of aluminum is drawn into a thin wire.

12. Circle all which are kinds (forms) of energy.

sound  color  chemical  dissolution  light