THE INTEGRATION OF ART INTO THE SECONDARY CHEMISTRY SCIENCE CLASSROOM

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ABSTRACT

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This study examined the impact of relevance and interest to the students on their achievements in chemistry. Interactive-engagement methods were expected to have positive effects on students' understanding of chemistry concepts. Art would also act as a motivator in students' interest and participation. By integrating art into chemistry it was expected that students' would make connections that better promoted understanding of basic, key scientific concepts in chemistry and an awareness of the chemical basis that underlies the art. It was proposed that art based lessons would lead to improved understanding and retention of core concepts as measured by pretest, post-test, classroom engagement and meeting the course requirements for completion. As shown by the pretest and post-test students showed significant growth in understanding the chemistry concepts presented. The conducted survey indicated that students were interested in the art-based activities and learned from them as well.

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INTRODUCTION

One of the most difficult aspects of teaching is finding ways to engage students, not only gaining their interest but to tie that to sound science. Additionally, difficulties arise if the material is too demanding, or watered down science that doesn't provide the necessary depth of knowledge (Kelly, Jordan, & Roberts, 2001). The integration of art and science has provided a number of educators a way of sparking students' interest, showing how science is found in every day experiences and giving students a personal connection to the science (Shapiro, 2010). Art is a subject with a natural, almost universal appeal rich in science and mathematics (Kelly, Jordan, & Roberts, 2001). Some high school and middle school teachers using STEM (Science, Technology, Engineering and Math) curricula are adding an A for Art in STEAM. Adding art is eliciting a wider range of student responses and participation. Having an artistic representation of students' ideas and solutions is a way to make learning personal (Shapiro, 2010). In 2004, twenty-four high school teachers from across the United States participated in a professional development program to field test an Artist as Chemist unit. The problem based model challenged students to create an original artwork and describe the chemistry principles involved in their work. These teachers found the students' work resulted in correctly explained chemical concepts and artistic works that were both original and creative. Perhaps most importantly it provided an opportunity for all students to succeed. They became an artist because of their chemistry knowledge and became a chemist because of their need to understand materials and their interactions (Eisenkraft, Heltzel, Johnson, & Radcliffe, 2006). This integration is taking place at the college level as well. The Mellon College of Science and the School of Art offered a joint course designed to have students use chemistry to create art. Students learned that the distance between chemist and artist increased when mass-produced and marketed art materials became available in the nineteenth century. This course brought the two fields back together and allowed the students to gain an appreciation for the difficulties and pleasures of both and to use their chemistry skills in an experimental and creative way (Pavlak, 2006). Chicago's Columbia College has a requirement that students take a semester long course that integrates science or math and art. Students are expected to use their talents and express creatively their understanding, wonder about or criticism of any math or science concept, its impact and its implication (Papacosta & Hanson, 1998). At the Wiley H. Bates Middle School in Annapolis, Maryland art has been integrated through all subjects. The school has developed a program that merges arts standards with core curricula to build connections and provide engaging content. They decided to become an arts integrated school as the primary initiative in a whole-school reform (Nobori, 2012). In the Philippines a study by the National Institute for Science and Mathematics Education Department that took place in 2011 determined the effects of an art-based chemistry class on high school students' understanding, using a control group of students being taught the same material without these art activities. By use of a pre-test and post-test their research showed that those students doing art-based chemistry activities showed a significant increase in understanding over those students not participating in the art activities (Danipog & Ferido, 2011).

Based on these courses in other schools the question becomes: will art-based lessons with students at Mott Middle College High School lead to increased student understanding and retention of core chemistry concepts as measured by a pre-and post test? Mott Middle College High School is a middle /early college that was established 22 years ago. Currently students are required to commit 5 years to their high school education and earn a minimum of 15 college credits to graduate from high school. Students apply to the school by attending an informational meeting with a parent or guardian, taking a placement test and interviewing with a school counselor. In the 2013-14 school year Mott Middle had a population of 371 students, 140 males and 231 females. The majority of the students, 79%, qualified for free or reduced lunch. Most (78%) were designated as minority students with 77% coming from the city of Flint and the other 23% from other Genesee County schools.

It is expected that using art-based activities with the students from Mott Middle will

- improve learners' visual perceptions to more accurately form mental models of science concepts.
- allow abstract concepts to be represented in concrete terms.
- motivate students by increasing their interest, connecting science more effectively with their personal and cultural lives.
- provide differentiated instruction, reaching more learners.
- enhance the students' working memory with increased attention and engagement.

To increase students' understanding of new content teachers need students actively processing the content. One of the methods for doing so is providing situations for students to form nonlinguistic representations such as making physical models and drawing pictures. Research results for nonlinguistic representation show significant gains in students' understanding and recall of information (Marzano, 2007). It has been shown in brain-based research that teaching practices that are used with art integration improve comprehension and long-term retention (Presidential Committee on the Arts and the Humanities, 2008). By creating stories, pictures and other nonverbal expressions of content, a process called elaboration, students are better embedding the information (Nobori, 2012). A neuroanatomist in the United

States, Marion Diamond, states that brain growth is the result of interacting with enriched environments characterized by novel changes, stimulation of all the senses and opportunities for free choice and self-direction (Barell, 2003). Learning new subjects and exploring different challenges stimulates the brain well into maturity (Wolf & Brandt, 1998). By integrating art into science students have the opportunity to use their senses, have choices in the art they create and experience the changes that matter undergoes in the creation of their art. Cognitive psychologist Richard Mayer has explored the link between multimedia exposure and learning and found that groups in multisensory environments always do better in accurate recall and demonstrate more creative solutions on problem solving than in unisensory environments. In some cases the improvement in recall and problem solving activities was as high as 75%. The more visual the input becomes the more likely it will be recalled. When information is presented orally, 72 hours later people recall about 10%. If a picture is added they remember 65%. The more elaborately people can encode what they encounter, especially if it can be personalized, the better they remember (Medina, 2008). By linking a chemistry concept with an art project students will have a multisensory and personal experience that will help them remember the scientific ideas.

In today's world of fast paced video games and instant answers from Google it can be a challenge to engage students in the classroom. Researchers and theorists have different definitions of engagement, from participation to time on task. It may be best described as, "When engagement is characterized by the full range of on-task behavior, positive emotions, invested cognition, and personal voice, it functions as the engine for learning and development." (Marzano, 2007). For any of this to occur the student must be paying attention. The more the brain pays attention, the more elaborately the information will be encoded, thus enhancing retention. Researchers have shown interest is inextricably linked to attention (Medina, 2008). In addition research has shown that across individuals and subject areas, interest has a powerful effect on cognitive functioning. Theorists suggest that interest may be the important first step in learning and later to differentiate between those expert and moderately skilled. Researchers recognize two types of interest, individual and situational. Individual interest is something that develops over time in relation to a particular topic and comes from increased knowledge, value and positive feelings. Obviously, individual interest is a determinant of academic learning but little is known about how such interests develop, why some early interests lead to long term interests or how to best utilize students' individual interests. Situational interest is a result of certain conditions in the environment that focus attention, leading to a more immediate reaction that may or may not last. When situational interest continues over time due to increased knowledge, value and positive feelings, it may make a significant contribution to the motivation of students. Situational interest can contribute to the development of long-lasting individual interest. Teachers have little to no influence over individual interests that students bring to the classroom but they can influence the development of such interests by fostering situational interest. When students become engaged in academic tasks there is a chance that genuine interest and even intrinsic motivation will result (Hidi & Harackiewicz, 2000). Novelty stimulates the brain and can stimulate situational interest. Because adolescents are especially influenced by our fast paced world it makes sense to provide unique experiences to reengage them (Wormeli, 2007). Integrating art into chemistry is a novel experience, one that should capture their initial interest. It is expected that over the course of *The Chemistry of Art* class, this situational interest will develop into individual interest. Some students will come to the class already having an interest in art and some will come with an interest in science. By integrating the two, each of these separate groups will have the opportunity to learn new concepts from and appreciation for each of these areas. Specifically for *The Chemistry of Art* it is believed that expressing chemistry aesthetically will provide a way to enhance students' interest in chemistry and encourage them to be further engaged in the discipline (Danipog & Ferido, 2011).

Artists must study and understand the properties of the materials they use to create their art, thus artists are chemists (Eisenkraft, Heltzel, Johnson, & Radcliffe, 2006). Like artists, scientists should feel free to express their emotional appreciation of the miracles of nature without others questioning their objectivity. Imagination is crucial to both science and art. Einstein is quoted as saying "Imagination is more important than knowledge." Imagination provides the drive for both the artist and the scientist to explore and experiment. The physicist Robert Oppenheimer in a speech at the Columbia University Bicentennial Anniversary celebration in 1954 said:

> Both the man of science and the man of art live always on the edge of mystery, surrounded by it; both always, as the measure of their creation, have had to do with the harmonization of what is new and what is familiar, with the balance between novelty and synthesis, with the struggle to make partial order in total chaos. (Papacosta & Hanson, 1998).

Science and art are both quests to examine and explain the world. Curiosity, creativity, imagination and attention to detail are common to artists and scientists and driven by the desire to discover things about one's world. Both rely on observing, asking questions, seeing patterns and constructing meaning (Shapiro, 2010). With so much in common the integration of art and science is logical in that they compliment one another.

In today's educational system knowledge is divided into disciplines. Traditional instruction typically breaks complex concepts into parts, teaching students in stages. Once the various parts are taught the student then must piece these together to see the whole picture. A focus on the parts result in lack of clarity of the whole and a focus on the whole may result in missing the intricacy of the parts. What is needed is a balance. The assertion in interdisciplinary studies programs, like art and chemistry is that visual and performing arts contribute to a students' success because they develop the intellectual skill of interconnectedness between the whole and the parts. Integrated courses allow thinking to occur in several ways. It also provides thinking strategies for inquiry, analysis and understanding, pushing students toward discovering universal principles between isolated facts. Interdisciplinary studies remove the overspecialization of science while teaching interconnected thinking (Hull, 2002).

Integration allows students to improve memory by having multiple references for a concept. By creating a model they have a visual interpretation to help reinforce and explain concepts. By having art and science be the integrated subjects goes even further. Scientists and artists use the same processing skills of engaging curiosity, asking questions, making observations, looking for patterns and constructing meaning. Both have been and continue to be ways to examine and explain the world. Curiosity, imagination, creativity and attention to detail are traits common to artists and scientists (Shapiro, 2010). Curiosity fuels imagination, which is the basis for creativity that drives the artist and the scientist to explore, experiment, synthesize and to take knowledge to a new frontier (Papacosta & Hanson, 1998). The National Science Education Standards state that students should understand the relationships between form and function while the National Standards in Art Education state that students should integrate form and function in making connections to other content areas in representing art and design principles. Artist and scientists practice standard procedures using precise terminology in their communications with peers and the public. They also practice observation skills that are the core of their work, design experiments (approaches) to test their hypotheses, use prior knowledge to inform their current work, follow standard protocols in their experimentation and reflect on their product before presenting it to others (Medina-Jerez, Dambekains, & Middleton, 2012). As artists study and understand the properties of the materials they use and find ways to use these materials to express themselves, they become chemists as well (Eisenkraft, Heltzel, Johnson, & Radcliffe, 2006).

Art and science have been integrated throughout the ages, most notably in the past by Da Vinci from his anatomical drawings to those of flying machines that closely resemble modern helicopters. During the Renaissance period artists conducted experiments with pigments. Even earlier smelting practices combined with art to create ancient bronze figures and jewelry. In the late nineteenth century an art and science interdisciplinary approach called the 'Nature study' was established in which students made accurate observations and sketches while studying objects, organisms and processes they found in nature (Medina-Jerez, Dambekains, & Middleton, 2012). Two current examples of people who have combined art and science are Diana Dabby and Steven Kurtz. Diana Dabby is an electrical engineering and music professor at Olin College. She began as a pianist who went back to college and eventually onto graduate school at MIT. Her doctorial thesis centered on the question: How could music come from chaos? She developed a mathematical theory that produced an unlimited number of musical variations from a single source (Edwards, 2008). Steven Kurtz is an artist and Professor of Art at SUNY Buffalo. Steven Kurtz's work incorporates bio-art. Bio-art involves using live tissues, bacteria and living organisms (Pasko, 2007). His work included an exhibit about genetically modified agriculture for the Massachusetts Museum of Contemporary Art. Perhaps future artists will influence public perceptions of science. One photo, painting, sculpture poem, film or article may transform the public image of science more than the work of many scientists (Papacosta &

Hanson, 1998). Perhaps this will occur if we recruit artists that have seen how closely science and art really are by incorporating the two (Laszlo, 2003).

METHOD

The implementation of this course took place during the Spring Semester at Mott Middle College High School. The Spring Semester was a very short time period of only five and one half weeks. The class met for approximately 90 minutes a day. The students enrolled in the course had unsuccessfully taken a 16-week Chemistry class earlier in the year using instructional methods such as text book reading, note taking, lecture, traditional laboratory activities and in class practice worksheets. Thus this class, *The Chemistry of Art*, was for credit recovery. Students were in the 4^{th} or 5th year of a five-year program. Of those students in their 5^{th} year this class was required for June graduation. Three of the twenty students enrolled in the class were 5^{th} year students. These three were part of the group of thirteen students that gave consent/assent (Appendix L) to participate in data collection for the class. In addition to the previous chemistry class, students had completed biology and physical science. Some had also taken a physics class.

Students were given a pretest (Appendix A) one of the first days of class. Six concepts were covered at an introductory level consistent with high school content expectations. They included: Matter, the Atom, the Periodic Table, Bonding, Chemical Reactions, Acids and Bases. Each of the concepts incorporated an art activity, or in the case of the Periodic Table, the construction of a model. Videos, short lectures, worksheets, construction of concept maps and class discussions were also part of instruction. Table 1 below is the course overview illustrating the topics covered, the objectives to be met for each topic and the art activity that was incorporated with each topic.

Table 1: Course Overview

Topic	Days	Objectives	Art Activity
Matter	1-5	Distinguish between chemical and physical changes/properties. Distinguish between elements, compounds and mixtures	Chromatography Fresco Henna
Atom	5-13	Identify the parts of the atom, their location, and relative charges. Use the atomic number and mass number to determine the number of protons, neutrons and electrons. Identify an element from its number of protons. Describe what occurs when ions form. Determine the molar mass of a compound. Calculate the number of moles in a sample.	UV Blue Print Chalk Drawing
Periodic Table	14-16	Relate similar chemical and physical properties to placement on the periodic table and valence electrons. Classify elements based on their location. Write electron configurations using the noble gas notation. Predict oxidation states for elements from placement on the table.	3-D Model of the Periodic Table
Bonding	17-20	Predict if bonding between two elements will be ionic or covalent. Name and write formulas for binary molecules. Name and write formulas for ionic compounds with representative elements. Explain why ionic solids have higher melting points than covalent solids.	
Chemical Reactions	20-22	Identify and model the five basic types of chemical reactions. Describe a photochemical reaction.	Cool Lights
Acids and Bases	23-26	Predict products of an acid-base reaction. Describe tests to distinguish an acid from a base. Classify solutions as acidic or basic given the pH. Explain why acids and bases are electrolytes.	Acids and Bases

In the first unit matter was the main topic. Students learned the differences between substances, mixtures, physical changes and chemical changes. The activities incorporated into this unit were *Chromatography, Painting a Fresco* and *Henna*. In *Chromatography* (Appendix B) students learned that many types of ink are a mixture and those that are water-soluble may be separated by water, while those that are "permanent" may be separated by isopropyl alcohol. Polarity and size of molecules were discussed to help explain why some colors of ink moved further along the paper. Through viewing video, students observed different types of chromatography. Real life uses of chromatography in industry, air quality control and forensic science were part of class discussion. In the laboratory students observed how different ink from the marker moved on coffee filter paper, discovering which were pure pigments and which were mixtures of different colors. They used this knowledge, a lesson on the color wheel and the rule of thirds to make their own abstract art piece on a coffee filter using water-soluble markers. Many enjoyed the process so much they created multiple pieces.

Painting a Fresco (Appendix C) was done to illustrate chemical change. Students created a fresco using Plaster of Paris and tempera paints. A brief lesson on the chemical makeup and history of Plaster of Paris was included along with background information on frescos. Students were able to detect that a chemical change occurred with the generation of heat, one of the common indications of chemical change, as the calcium sulfate reacted with the carbon dioxide in the air. They learned through trial and error the importance of not spreading their plaster too thin and that mixing the paint with the plaster did not allow for sharp detail. A trip to the Flint Institute of Art allowed them to see a fresco and an art piece done by Helen Frankenthaler, who used a painting technique similar to the process of chromatography.

Henna (Appendix D) art as temporary tattooing was used to reinforce the concept of physical change. Students were shown how henna enters the top layers of the skin as a stain. Background information regarding henna's history, uses, chemical composition, and natural sources was included. After viewing a number of designs and a video showing the basic technique of applying the henna paste students tattooed their own design on their hands and arms. Some were more aesthetically appealing than others and some stained the skin longer than others but most enthusiastically participated. It is often difficult by observation alone for students to distinguish between physical and chemical changes. All three activities, *Chromatography, Fresco* and *Henna* reinforced that fact.

UV Blueprint Design (Appendix E) tied in chemical changes and ions as part of the unit on the Atom. Along with the simple components of the atom (proton, electron and neutron), how atoms become ions and the formation of ions to increase stability was discussed and practiced through a number of assignments. Students learned that a photochemical reaction is a chemical change that requires UV radiation to occur. They made UV sensitive fabric using iron salts, which provided iron ions that resulted in the formation of Prussian blue when exposed to UV radiation. Prussian blue is a dark blue color as a result of the iron(II) and iron(III) ions in the compound $Fe_4(Fe(CN)_6)_3 \cdot H_2O$. Then they created a design that ranged simply from their name to quite beautiful arrangements of found objects, from flowers to metal washers that were placed on the fabric. When the fabric was exposed to sunlight no reaction could take place in those areas covered by the objects. Exposed areas turned blue as the reaction occurred. Despite a somewhat overcast day the reaction worked as expected.

In this class the topic of the mole was introduced, not having been part of the original 16-week Chemistry course. The mole was presented first as a way of counting and compared to a dozen, gross and ream. Then the relationship to the mole and molar mass was established. Students practiced finding the molar mass of elements and compounds and using the molar mass to determine the number of moles in a sample. *In Creating a Chalk Drawing* (Appendix F) students created a high contrast portrait using black paper and colored chalk. With out specific directions they needed to determine what to measure and how to calculate the number of molecules used in their piece of art. They were able to determine the number of calcium sulfate molecules used in their portrait from the mass of chalk. Although the value they obtained was probably very inaccurate the experience of calculating the value was significant. Many had difficulty reflecting on why this was such a large number.

During the unit on the Periodic Table students reviewed periods, key families, the location of metals, nonmetals, metalloids, representative elements, transition elements, and inner transition elements by coloring and labeling a periodic table. They also practiced writing electron configurations using the noble gas configuration and predicting the number of valence electrons. In *Constructing a 3-D Model of the Periodic Table* (Appendix G) they made a three dimensional model that allowed them to see the s,p,d and f blocks and their relationship to the electron configuration. It also provided a better visualization of where the inner transition metals actually fit into the periodic table. For some students following written directions in the construction of the 3-D model was a challenge but all were successful and able to use the model to answer questions about the elements.

Throughout the course the idea that atoms will lose, gain or share electrons to become stable had been emphasized. This led to the topic of ionic and covalent bonding. To distinguish between ionic and covalent compounds a demonstration of the conductivity of tap water, distilled water, salt water and sugar water was performed. The ability of similar amounts of salt and sugar (a teaspoon of each) to dissolve in water was also noted. Students' questions and responses indicated that they were engaged in the demonstration. Placement of the elements on the Periodic Table with their ability to lose, gain or share electrons was reviewed. Naming of some simple ionic and covalent compounds was introduced to some students for the first time. The task of balancing ionic charges made writing chemical formulas difficult for most. Much more time would have been required for them to become competent in this skill. Writing formulas and naming covalent compounds proved to be much easier for the students.

Types of chemical reactions is another topic that is not covered in the 16-week Chemistry class but is introduced in Physical Science during the students' first year of high school. After viewing a video using the Flintstones to model the five basic types of chemical reactions students developed their own models. Many were very creative, using Pac Man and Ghost, to articles of clothing, to geometric shapes. All were able to demonstrate understanding of the patterns that describe these types of chemical reactions and how they can be used to make predictions of possible products. In *Cool Light* (Appendix H) glow sticks were used to illustrate a chemiluminescent reaction. Students were given information about the reaction that occurs when the inner tube of Cyalume, diphenyl oxalate, is broken and mixes with the outer tube that contains hydrogen peroxide and a dye. The oxygen atoms in the peroxide break resulting in a great deal of energy that causes the dye molecule to fluoresce. As an illustration students were able to view the reaction occurring outside the tube. Using slow shutter speed photography students created some incredibly interesting photographs moving their glow sticks in various patterns around the dark classroom.

Acids and Bases (Appendix I) were the last unit of instruction. This topic was also first introduced in Physical Science but not covered in the 16-week Chemistry course. The topic was limited to the Arrhenius definition of an acid and a base in which common properties of acids and bases were presented. In the laboratory students tested six known solutions and four unknowns with cabbage juice indicator, litmus paper and phenolphthalein. They were able to accurately determine if each of the ten solutions was an acid or a base. Their ranges of pH were generally acceptable for each of the ten solutions. They were also able to infer which indicator would be most useful with a variety of solutions. Students were shown a variety of pictograms and symbols used in the past and by different cultures for communication. They were encouraged to use one or more of these symbols to reflect something personal about them. Using dropper bottles they applied one or more of the previously used ten solutions to construct the symbol onto acid free tissue paper. They then sprayed the tissue paper with cabbage juice indicator to achieve the desired color palette. Only a few were truly creative, instead opting to draw such things as their initials, hearts and flowers! The tissue paper allowed the solutions to considerably spread. Using acid free card stock would likely result in more distinct lines and shapes.

The descriptions given are focused on the art aspect of the class. As previously mentioned short lectures to introduce or reinforce topics, class discussions for clarification, construction of concept maps to unify topics, and worksheets for practicing skills were all part of instruction. Approximately once a week students were given a quiz (Appendix J) to assess their understanding of that weeks' lessons. At the end of the course they took the post-test (Appendix A), which was the same as the pretest.

RESULTS

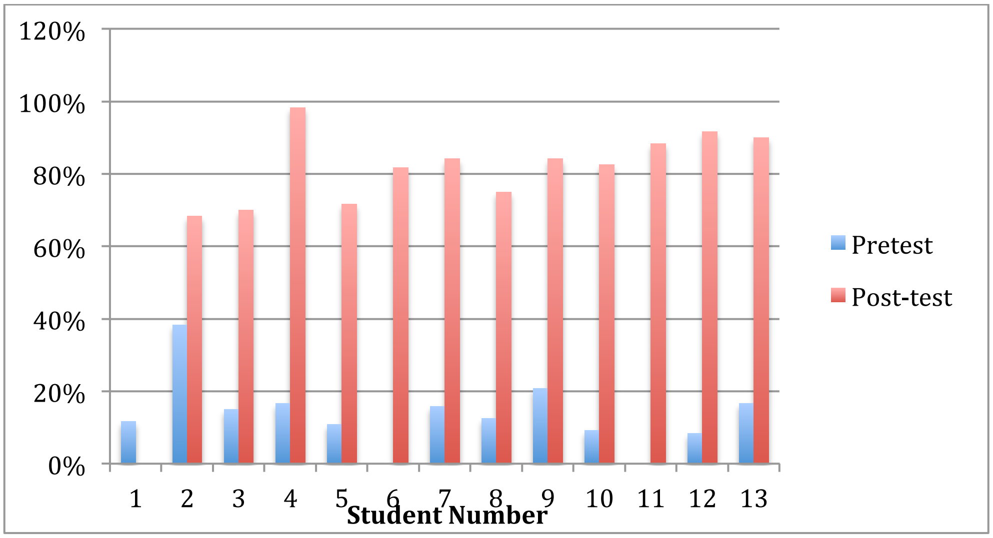
Of the twenty students enrolled in the course *The Chemistry of Art*, thirteen gave assent/consent to participate in the data collection. Comparisons between pre and post-test scores were made as well as quiz scores. In addition an analysis of a class survey (Appendix K) was conducted. Table 2 illustrates the scores for the pretest, quizzes and the post-test.

Table 2: Averages for the 13 students on pretest, quizzes and post-test, n=10

Student	Pre-test	Quiz I	Quiz II	Quiz III	Quiz IV	Quiz V	Post-test
	37 questions 60 possible points	9 questions 18 possible points	9 questions 15 possible points	8 questions 8 possible points	7 questions 14 possible points	7 questions 10 possible points	37 questions 60 possible points
1	12%				100%		
2	38%	67%	87%	75%		85%	68%
3	15%	75%	77%	75%			70%
4	17%	83%	120%	63%	79%	50%	98%
5	11%	53%	60%		29%	90%	72%
6		78%		63%			82%
7	16%	53%	93%	88%	68%	70%	84%
8	13%	61%	67%	38%	82%	75%	75%
9	21%	61%	73%	38%	50%	65%	84%
10	9%	72%	80%	50%	57%	70%	83%
11		97%	107%	100%			88%
12	8%	67%	87%	63%	54%	90%	92%
13	17%	58%	93%	63%	57%	90%	90%
Average	**16%**	**69%**	**86%**	**65%**	**64%**	**76%**	**82%**

Figure 1 shows the pretest and post-test scores for the 13 students who gave assent/consent.

Figure 1: Graph of the 13 students pretest and post-test results



The pre and post-test were identical and consisted of 37 questions with 60 possible points. Students were asked to identify, describe, explain and name. Each of the six units was represented on the test. Each of the quizzes (Appendix J) generally consisted of questions taken from the pretest that were addressed that week in class. Quiz I dealt with the unit on Matter, Quiz II with the Atom, Quiz III with the Periodic Table and the Mole. Quiz IV was an exception. This quiz included questions on ionic and covalent bonding and types of chemical reactions. Types of chemical reactions were not part of the pretest and not one of the topics intended to be included in the course. With time permitting it was added and Quiz IV in part assessed students' understanding. The last, Quiz V, assessed students understanding of Acids and Bases.

Of the thirteen students only ten took both the pretest and the post-test, giving ten complete pairs. Paired Student's *t*-Test (n=10 pairs) comparing the pre and post-test showed that the values are significantly different and not due to chance, with p=0.000. The pretest and post-test did not have any multiple choice or true/false questions and students trying to answer the questions spent little time. Students' pretest scores were similar with a standard deviation of

8.54%. Students made significant improvement on the post-test and again their score were similar as shown by a 8.91% standard deviation. Quiz scores were not nearly as consistent but in general students made improvements over the pretest scores with the exception of student 11 who did not take the pretest and who had higher quiz scores than post-test score. Student 2 made progress from pretest to the quizzes but little progress after that. Student 6 also did not take the pretest and Student 1 did not take the post-test nor complete the class.

After each activity students were asked to reflect and rate each activity on a scale of 1-5, with 5 being the highest, in four categories: Collaboration, Thinking, Interest, and Learning. Collaboration was described as working cooperatively with others and/or actively participating. In Thinking students were asked to reflect on whether the activity was mentally engaging. With Learning they were asked to rate how well the activity helped model the topic in a way that helped their learning. Only eight of the 13 consenting students turned in the survey.

Table 3: Averages for 8 students' survey on the art activities, scored 1-5, 5 being high

Activity	Collaboration	Thinking	Interest	Learning
Fresco	4	4.2	5	4.8
Chromatography	4.2	3.9	4.1	4.2
Henna	3.4	3.9	4.1	4.4
UV Blueprint	4.7	4.3	4.6	4.6
Chalk Drawing	4.8	4.5	4.1	4.8
Model of Periodic Table	4.8	4.2	3.5	4
Cool Lights Glow sticks	4.4	4.4	4.6	4.7
Acids & Bases	4.2	4.2	4.2	4.2

Students that responded to the survey were most interested in one of the first activities, the fresco, representing a chemical change. They were the least interested in constructing the 3-D Model of the Periodic Table. The *Chalk Drawing*, finding the number of particles of chalk used in a portrait required the most thinking and learning. They appeared to have the most fun with the Glow sticks and this activity received one of the highest scores in the Interest category.

Based on the pretest and post-test scores 10 students showed a significant increase in understanding of the chemistry. All students showed improvement from pretest to all quizzes, thus indicating student growth took place. All of the students earlier this year during a previous semester failed the course but after this class 12 of the 13 participating students earned a passing grade of 70% or greater.

DISCUSSION

It was proposed that integrating chemistry and art would improve students' understanding of chemistry concepts for students who had not previously been successful in a 16-week Chemistry course. By comparing pretest and post-test scores (Table 2) it was determined that students made connections between chemistry and art that promoted understanding of chemistry concepts. The student survey shows that art acted as a motivator in students' interest and learning. Art provided a visual framework that allowed students to form a mental model and to represent abstract concepts in concrete terms. Motivated students had increased engagement and attention that fostered learning. Integrating art and chemistry provided a way to differentiate learning, teaching in a way that best allowed students to learn.

The 16% pretest average may not have been a true measure of student knowledge. In the past students have attempted to answer multiple choice test questions but generally leave short answer and problem solving questions unanswered. This test had no multiple-choice questions. This and the observed short time period students spent on the test indicated that not much effort was made. Never-the–less, none of these students had previously passed the chemistry course and it may be inferred, had limited knowledge. The post-test average of 82% was a significant improvement compared to the pretest. In addition, the small range in scores indicates that all 10 of the students taking the post-test had gained understanding and knowledge of the material. Upon reflection the test could be improved by including more questions that required synthesis and other higher order thinking skills rather than merely recall.

It may be argued that students were more motivated to pass the class after previously having been unsuccessful. One could also say they were more likely to be disinterested and unengaged due to their previously poor experience. Doing the art projects proved to be engaging for the students. This class showed that becoming engaged in a task resulted in interest and motivation (Hidi & Harackiewicz, 2000). Interest and motivation are linked to attention, a necessity for learning to take place.

It was important to present the material in a different way than had previously been done. Nonlinguistic representation has been shown to improve students understanding and recall of information (Marzano, 2007) and when creating pictures and nonverbal representation students are better at learning the information (Nobori, 2012). Therefore, having the students make an art piece that represented a chemistry concept helped them understand and recall that concept. Incorporating art allowed for an additional method of instruction using engaging tasks that included nonlinguistic representation.

It was emphasized in all the art projects that experimentation was taking place, never knowing exactly what might be the final result. In both science and art the participant designs the experiment using prior knowledge, follows standard protocols during the experiment and then reflects on the product. This allowed students to see that following a procedure is not limited to the discipline of science. The integration of science and art also allowed the student to see how they can be creative in both disciplines. In addition to being creative their products were personal. The more personalized the exposure the better it is remembered (Medina, 2008).

In the *Chromatography, Fresco and Henna* art projects students were able to make personalized and creative projects while learning the differences between physical and chemical changes. Most often at the beginning of any chemistry course students describe a chemical change merely as one that cannot be changed back. They also may believe that a color change is proof of a chemical change. The art activities provided examples that a color may be an indicator, not proof, of a chemical change. They also illustrated that it can be difficult by observation alone to determine if a chemical reaction has occurred. All three activities offered opportunities to show how the science concepts can be found in real life situations, making the concepts more relevant. More time should have been given for *Chromatography* to allow for more reflection and discussion on the R_f values.

In *UV Blue Print Design* students again made a creative, personalized piece of art. In addition they learned a little about photography and photochemical reactions. Discussions took place about how lenses work, including how the lens in the eye functions. These were discussions that enriched the chemistry concepts. With more time allowed students could make their own solutions for the experiment in the laboratory, thus having an opportunity to practice measuring solids and liquids.

One of the topics not covered in the original 16-week course was the mole and molar mass. In *The Number of Particles in a Chalk Drawing* students were able to make a concrete piece of art to represent an abstract concept. This activity was inquiry based in that no specific directions were provided. With very little prompting students were able to determine that the difference in mass of the paper before and after they drew the picture would provide the mass of the chalk. Most required some help with the mathematics of converting this to moles of chalk and then to particles of chalk. This very concrete activity provided an excellent introduction to the more abstract concept of the mole and the number of particles in a sample. Their limited comprehension of numbers written in scientific notation and even decimals, limited their understanding of the significance of this very large number. A brief discussion and review of the use of scientific notation would have been of benefit.

There was no creative aspect to *Creating a 3-D Model of the Periodic Table* but having a three dimensional model did allow students to better understand how the inner transition elements fit into the periodic table. It also allowed them to see that the table doesn't start and stop as one goes from one period to the next as it appears in the common two-dimensional table but rather continues smoothly from one element to the next. The color gradient on the model served to show which elements had similar properties and how they varied from one group to the next. The model was useful when writing electron configurations using the noble gas method.

In *Cool Light* students again were able to be creative and make a unique photographic image. Using a toy they had all played with in the past, learning the chemistry behind it and then making something creative allowed the students to form connections between the chemistry and their lives. This resulted in the learning being more personalized and better remembered. This unit could have been improved by initially giving the students time to ask their own questions about the glow sticks and have them then conduct an experiment to answer one of their questions.

In *Acids and Bases* students took part in a traditional laboratory experience, finding the color of a number of known and unknown solutions when using three different acid-base indicators. They used that information to determine the pH of each of the solutions. Students were able to see the limitations in determining pH when using an indicator. They were then able to make it more personalized and to apply what they had learned to make a piece of art. This visual provided another way for them to recall what they had learned about acids and bases and their pH values. In place of the tissue paper using a less absorbent paper would result in a sharper image.

By incorporating art into the chemistry class students were able to make visuals that helped them recall the chemistry information. In addition they were able to connect abstract concepts to concrete images that improved their understanding of the chemistry material. Perhaps the most significant benefit was that using art was a novel idea that intrigued and interested the students. Students don't learn if they're not paying attention. Including the art provided a way to grab their attention. By incorporating art the required chemistry concepts were taught in a different way, a differentiated approach. The *Chemistry of Art* class was a success and should be used again for the Spring Semester credit recovery class.

APPENDICES

APPENDIX A

Pretest and Post-test

Figure 2: Pretest/Post-test

The Chemistry of Art Name ___________________

Pre-test/Post-test

1. Identify each of the following as a physical or chemical change
    a. Wax melting
    b. Silver tarnishing
    c. Banana rotting
    d. Water evaporating

2. Identify a physical and a chemical change that you could do to a piece of copper.

3. What are some indications that a chemical change has taken place?

4. Distinguish between an element and a compound.

5. Distinguish between a substance and a mixture.

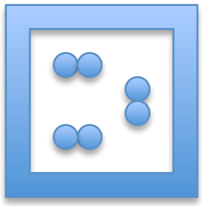
6. Distinguish between a heterogeneous and homogeneous mixture.

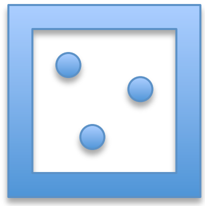
7. Describe a mixture and how to separate it.

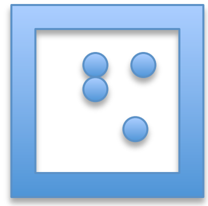
8. Which of the following is not an alloy: brass, bronze, tin, or stainless steel? Explain your choice.

Figure 2 (cont'd)

9. Use the terms *element, compound* and *mixture* to describe the composition of each of the figures below:

a. 

b. 

c. 

10. Define an atom.

11. How can atoms contain charged particles and still be neutral?

12. What holds electrons within the atom?

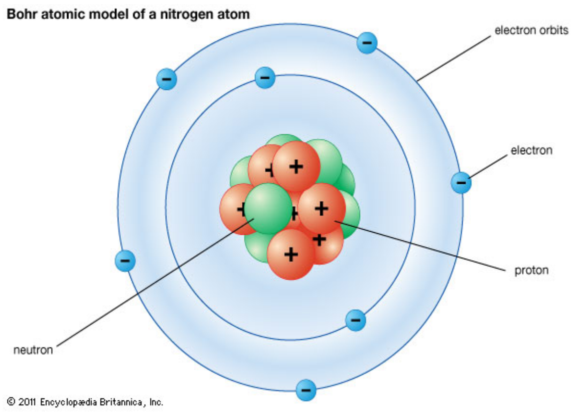
13. What particles are found in the nucleus?

14. An atom of chlorine with the atomic number of 17 has an atomic mass number of 35. Determine the number of
    a. protons
    b. electrons
    c. neutrons

15. What is the relative charge on the
    a. proton
    b. electron
    c. neutron

Figure 2 (cont'd)

16. What element does this Bohr model of the atom below represent?



17. An element has similar chemical properties as fluorine and chlorine with an atomic number greater than calcium and less than krypton. Use the periodic table to identify the element.

18. Select something that displays repeating properties. Describe it and explain how it corresponds to the periodic law.

19. Why do elements in the same group have similar properties?

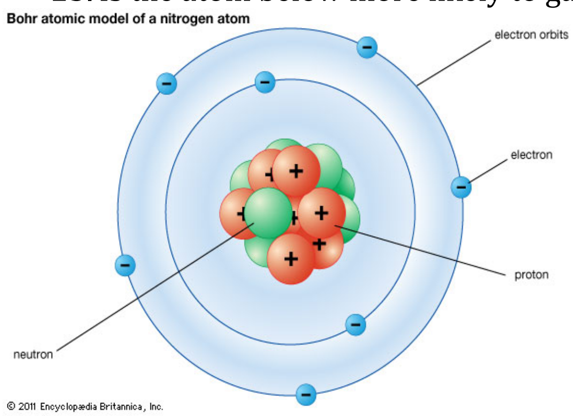
20. Using the periodic table classify each of the following as a representative element, transition element, an inner transition element or a noble gas:
    a. Aluminum
    b. Magnesium
    c. Argon
    d. Cerium
    e. Titanium

21. Atoms may form positive and negative ions. Describe what occurs when each type of ion is formed.

Figure 2 (cont'd)

22. In the reaction $Mg + S \rightarrow Mg^{2+} + S^{2-}$ which atom gained electrons and which atom lost electrons?

23. Is the atom below more likely to gain or lose electrons? Explain how you know.



24. A formula unit of calcium bromide has 2 bromide ions corresponding to each calcium ion in the compound. What is the formula for calcium bromide?

25. The melting point of sugar is much lower than the melting point of salt. Which is an ionic compound? Explain how you know.

26. In the chemical equation $2H_2 + O_2 \rightarrow 2H_2O$ which is(are) the reactant(s)?

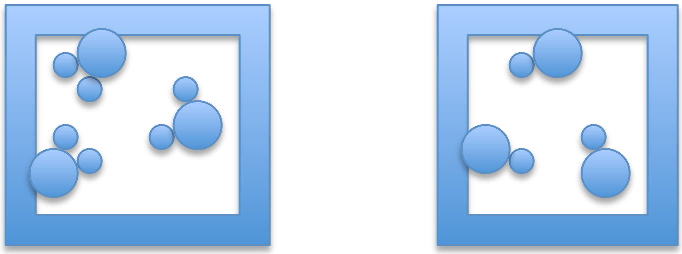
27. A mole is an amount equal to Avogadro's number. What is the value of this number?

28. What is the molar mass of H_2O?

29. How many moles of copper atoms are in 63.5 grams of copper?

30. Do samples A and B below contain the same number of moles of atoms? Explain your answer.

Figure 2 (cont'd)



31. What is a photochemical reaction?

32. Why are photographic and blueprint chemicals stored in dark bottles?

33. Complete the following statements about acid-base pH values:
    a. The pH scale ranges from
    b. An acid has a pH
    c. A base has a pH

34. Name two properties of an acid.

35. Name two properties of a base.

36. What are the products of a reaction between an acid and a base?

37. Why do acids and bases conduct electricity when dissolved in water?

APPENDIX B

Chromatography of Inks

Chromatography of Inks

Name ____________________

Background Information:

Chromatography is a process used to separate mixtures. More than 150 years ago workers would test the strength and quality of a dye using chromatography. Today the technique may be used to determine the ingredients in a particular flavor or scent, test for the presence of a drug in the blood or isolate air pollutants. It can also be used to separate and purify products when making petroleum jelly.

The word chromatography comes from the Greek words “khroma” meaning color and “graphein” meaning to write or to represent. There are several types of chromatography but in all cases a substance is placed onto or into a medium and a solvent is passed through the test substance. The solvent is called the mobile phase and the medium is the stationary phase. High Performance Liquid Chromatography (HPLC) can separate liquids, and gases are separated by Gas Chromatography.

Paint on canvas is another example of chromatography where the paint is the mobile phase; the canvas is the stationary phase. Often when artist paint on canvas they treat it so that it doesn’t absorb as much liquid. Helen Frankenthaler used the absorbent property of canvas to create interesting shapes and patterns. She would pour paint onto a canvas tacked to the floor and let the way the paint moved help decide what the picture would be.

In this experiment paper or cloth is the medium (stationary phase), the test substance is ink and the solvent (mobile phase) is water or isopropyl alcohol.
The solvent will wick up the medium, mix with the ink and carry the pigments in the ink with it. Ink is a mixture and the different colored pigments will be carried along at different rates, ending up in different places. How fast each pigment moves depends on the size of the pigment molecule and how strongly the molecule is attracted to the medium due to polarity. The separated substances produce a pattern called a chromatogram. To determine the rate of movement for each component of the mixture the R_f value is calculated. The R_f value can be used to identify the components in a mixture because each component will have a unique R_f value.

R_f = distance traveled by the component/ distance traveled by the solvent

Materials:

Permanent ink markers	Cotton cloth
Washable ink markers	Pipette
Coffee filters	Rubber band
Paintbrush	
Beaker	
Skewer	
Isopropyl alcohol	

Procedure:

Part I

1. Choose 3 different permanent and 3 different washable markers. Using the strips of coffee filter place a concentrated dot of ink just above the pointed end of the strip. With a pencil mark this starting point for measuring the migration distance of each color. With a pencil label your strip with the type and color of the marker.
2. Using the skewer hang the strips over a beaker so that the pointed end almost reaches the bottom of the beaker.
3. Run a test with black ink to determine which solvent, water or isopropyl alcohol should be used for the two different types of ink, washable and permanent.
4. Add enough of the proper solvent to the beaker so that the pointed tip of the strips comes in contact with the solvent and **the ink dots are above the surface** of the solvent.
5. When the solvent front has neared the top of the strips remove the strips and place them on a piece of paper towel to dry.
6. Immediately mark the solvent front.
7. Immediately mark and label the leading edge of each individual color.
8. Measure and record the distance the solvent migrated from the starting point to the front.
9. Measure and record the distance each color migrated from the starting point to the leading edge of that color.
10. Calculate and record the R_f value for each color.

All data and calculations must be recorded in a data table.

Part II

1. Place a coffee filter on top of several paper towels. Use different colors of washable markers to create a design or pattern on the coffee filter.
2. Dip the paintbrush in the water and paint over the design with the wet brush. Rinse the brush in the water several times while you are painting with the water.
3. Place the coffee filter on a paper towel to dry.

Part III

1. Stretch your cloth over the beaker and keep it in place with a rubber band.
2. With the permanent markers create a design on the stretched cloth. Leave some space between colors.
3. Using the pipette drop isopropyl alcohol over your design.
4. Allow your cloth to dry.

Analysis:

Part I

1. What was your solvent for permanent ink? For washable ink?

2. Why did the inks separate?

3. Why did some ink colors move a greater distance than others?

4. Compare your R_f values with two other groups. Did you get the same values? Why or why not?

Part II

1. Identify the
   a. mobile phase
   b. stationary phase
   c. test substance

2. Describe how this activity connects to the process of chromatography.

Part III

3. Identify the
   a. mobile phase
   b. stationary phase
   c. test substance

2. Describe how this activity connects to the process of chromatography.

APPENDIX C

A Chemical Change: Paint a Fresco

Figure 3: Paint a Fresco

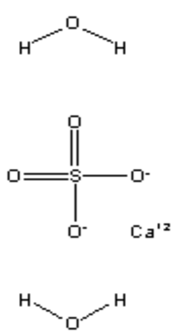
A Chemical Change: Paint a Fresco

Name ___________________

Background:

Fresco means "fresh" in Italian. Frescos are painting done on a thin layer of wet (fresh) plaster. Michelangelo Buonarroti painted one of the most famous frescos on the ceiling of the Sistine Chapel in Rome, Italy.

Gypsum is a common mineral, with thick, extensive evaporate beds found in sedimentary rocks. A large gypsum deposit at Montmartre in Paris led to gypsum being commonly referred to as "plaster of Paris". Gypsum plaster is a form of calcium sulfate ($CaSO_4 \cdot 2H_2O$). Calcium sulfate dihydrate is formed from the ionic bonds between Ca^{+2} and SO_4^{2-} held together by the intermolecular hydrogen bonding of water. The dihydrate means that there are two molecules of water for every molecule of calcium sulfate, held together with coordinate covalent bonds. Due to the weak intermolecular hydrogen bonding, plaster of Paris is quite soft and the bonds are easily broken.



When pigments are painted on the plaster the pigments sink into the plaster. The plaster is the medium that holds the pigments. A chemical change occurs when the plaster is exposed to the carbon dioxide in the air. As the chemicals combine the pigments get stuck in the plaster so it will not peel, chip or wash off. This is one reason frescoes last a very long time.

Materials:

Wax paper
Small disposable cup
Craft stick
Plaster of Paris
Paints
Tablespoon
Paintbrush
Cup for rinse water

Figure 3 (cont'd)

Procedure:

1. Place 2 tablespoons of plaster in the small cup. Add 1 tablespoon of water. Stir with the craft stick until smooth.
2. Pour the wet plaster onto the wax paper. Smooth the plaster out with the craft stick.
3. Dip the paintbrush into the paint and paint the plaster. To keep plaster out of the painter rinse the paintbrush each time the brush is dipped into the paint.
4. Allow the fresco to dry.

Analysis:

1. Define a chemical change.

2. What indicates that a chemical reaction takes place?

APPENDIX D

Henna

Henna

Name ________________

Background:

Henna's staining properties come from the compound 2-hydroxy-1,4-naphthoquinone, or by the more common name, lawsone. Lawsone is an organic compound that bonds with proteins. The lawsone is mainly concentrated in the petioles of the leaves of the henna tree, also known as the mignonette tree and the Egyptian privet. Henna is a tall shrub or small tree native to northern Africa, western and southern Asia and northern Australasia, both in semi arid and tropical regions. It produces the most dye when grown in temperatures between 35 and 45 ^{o}C.

Whole henna leaves will not stain the skin. The lawsone molecules must be released from the henna leaf by adding a mild acid. To form intricate patterns henna is generally dried, milled and sifted into a fine powder before the acid is added to form a smooth paste.

The released lawsone molecules that are about the same size as amino acids move from the henna paste into the stratum corneum, the outermost layer of the skin, without spreading. The stain appears darker with the thicker stratum cornneum on the hands and feet. Essential oils such as tree tea, lavender and eucalyptus, with high levels of monoterpene alcohols, improve the stain. Henna may appear different shades depending on physiological factors such as skin type, temperature, hormone levels and stress. After the dried paste is scraped off the skin oxidation with the air can further darken the skin.

Henna refers to the dye prepared from the plant and the art of temporary tattooing. Henna has been used dating back to 2100 B.C. to stain skin, hair, fabric and leather. It has also been used to cool the skin in hot climates. Henna flowers have been used to create perfumes. It can also act as an insect repellent and to prevent mold.

APPENDIX E

UV Blue Print Design

UV Blueprint Design

Background:

In black and white photography silver salts are coated on paper. When exposed to light the silver is reduced (gains electrons) from Ag^+ to Ag. This is a photochemical reaction, a chemical change caused by light. The areas most exposed to light form the most Ag atoms and appear black on the film negative. Areas not exposed to light remain white because no Ag^+ ions have been reduced. The fixing and washing of the negative removes the excess reactants, preventing further changes. Light is shown through the negative onto a photosensitive paper and results in a black and white photograph.

Making UV sensitive fabric is similar to this process. Using cloth that has been coated with a combination of two iron salts and exposing it to UV light results in a reduction of Fe^{3+} to Fe^{2+}. This is a photochemical reaction, a chemical change caused by light. In areas that are covered by an opaque object the chemical reaction cannot take place and the cloth remains its original color.

The iron salts are ferric ammonium citrate which provides the iron ion that is reduced and potassium ferricyanide which provides a hexacyanoferrate(III) ion in the reaction. The overall reaction is

$$Fe^{2+} + (Fe(CN)_6)^{3-} \Rightarrow \underset{\text{Prussian blue}}{Fe_4(Fe(CN)_6)_3 \cdot H_2O}$$

Prussian blue is a dark blue color due to the mixed iron(II)-iron(III) compound.

Materials:

- Ferric ammonium citrate solution
- Potassium ferricyanide solution
- Cardboard
- Gloves
- Graduated cylinder
- Opaque objects or patterns
- Paper towels
- Plastic container
- Black plastic bag
- Stirring rod
- Cotton cloth

Procedure:

Safety precaution: Prussian blue solution is nontoxic but will dye the skin a dark blue: its color will fade over time. Wear goggles and chemical-resistant gloves.

Part I: Preparing the cloth

1. Pour 50ml of ferric ammonium citrate solution into the plastic soaking container.
2. Pour 50ml of potassium ferricyanide solution into the same plastic soaking container. Stir the solution well with the stirring rod.
3. Place the cloth in the solution. Mix the cloth with the stirring rod to insure the cloth is completely wet.
4. Set out paper towels on the lab bench.
5. Remove the cloth from the solution, wringing out any excess solution over the soaking container.
6. Spread out the cloth on the paper towels to blot up any remaining solution.
7. Hang the cloth in a dark room to dry overnight.
8. Dispose of the solution as directed.

Part II: Developing the Images

9. Place the cloth on the cardboard and arrange the opaque object on the cloth.
10. Place the cloth and the objects in the black plastic bag and take it to a sunny location.
11. Remove the plastic bag, exposing it to direct sunlight until the cloth turns a dark blue color. This may take up to 20 minutes.
12. Remove the objects and place the cloth back into the plastic bag. Bring it back indoor out of direct sunlight.
13. Wearing gloves rinse the cloth under cold water to remove excess iron(III) ions. Rinse until the rinse water is clear and the cloth is a lighter shade of blue.

APPENDIX F

The Number of Particles in a Chalk Drawing

The Number of Particles in a Chalk Drawing **Name __________________**

Background:
A pair, a dozen, a gross, a ream and a mole are all terms used to represent an amount, a way of counting. Chemists use the mole to refer to the number of particles in a substance. One mole is equivalent to 6.02×10^{23} , a fundamental constant in chemistry. This is known as Avogadro's number in honor of an Italian scientist who proposed that equal volumes of gases at the same temperature and pressure would have equal number of particles. A mole is considered to be the number of atoms present in 12g of carbon-12. One mole of any substance has 6.02×10^{23} particles. Therefore, one mole of gold has 6.02×10^{23} atoms of gold and one mole of H_2O has 6.02×10^{23} molecules of water.

The molar mass of any substance can be determined from its atomic mass. For example the atomic mass of gold is 196.96 amu and 1 mole of gold would have a mass of 196.96g. Putting this all together we can see that 1mole of gold contains 6.02×10^{23} atoms and has a mass of 196.96g. 1 mole of water contains 6.02×10^{23} molecules and has a mass of 18.01g (15.999 +2· 1.007).

Chalk is a soft, while, porous sedimentary rock. It is a form of limestone with the chemical composition $CaCO_3$. Blackboard and sidewalk chalk are traditionally made of natural chalk but now are generally made from gypsum, $CaSO_4$.

Materials:
Colored chalk
Paper
Mass balance

Objective:
Create a chalk drawing.
Determine the mass of the chalk used in the drawing
Calculate the number of moles of chalk used
Calculate the number of chalk particles used

Procedure:
Design a procedure to meet the objectives. Include all of your data and calculations in an orderly fashion.

Analysis:
1. Explain why your number of chalk particles is so large.

2. How accurately do you believe this value to be? What are some possible sources of error

APPENDIX G

Creating a 3-D Model of the Periodic Table

Constructing a 3-D Model of the Periodic Table **Name ___________**

Background:

The main purpose of the periodic table is to show the various relationships among the elements. The term periodic means repeating or cyclic and the Periodic Law states that the properties of the elements repeat when the elements are arranged by increasing atomic number. A number of scientists have made various representations of the periodic table of elements. In this activity a 3-D model will be constructed. This is not a new concept but was done in 1862 by Alexandre Beguyer de Chancourtois, before Demitri Mendeleev, who is known as the father of the periodic table.

Materials:

Copies of periodic table
Scissors
Tape

Procedure:

1. Cut out the four pieces of the periodic table. **Do not cut away the grey background from the bottom edges or from the gaps between elements.**
2. Tape the inner transition metal piece (lanthanide and actinide series) onto the transition metal piece.
3. Tape the transition metal piece with the attached inner transition metal piece onto the main group piece.
4. Roll this entire section into a cylinder and tape.
5. Roll the noble gas section into a cylinder and tape.
6. Add tape to the outside of the noble gas section and attach it to the inside of the main group cylinder.

Analysis:

1. Along the main group cylinder how many elements are from noble gas to noble gas? Compare this to the possible number of s and p electrons in a specific energy level.

2. Scandium (Sc) and gallium (Ga) both lie below aluminum (Al). How will the properties of these two elements compare to the properties of Al?

3. How many elements make up the lanthanide series?

4. How many elements make up the actinide series?

5. The properties of the elements in the lanthanide series are similar to what element of the transition metals? How can you know?

6. Hydrogen occupies its own space; what does this indicate about its properties?

7. Name the halogens.

8. Name the noble gases.

9. Name the alkali metals.

10. The symbol n on the table represents a neutron. Having 0 protons it can be assigned an atomic number Z=0. What is the atomic number of lithium? How many protons are in lithium?

APPENDIX H

Cool Light

Figure 4: Cool Light

Cool Light

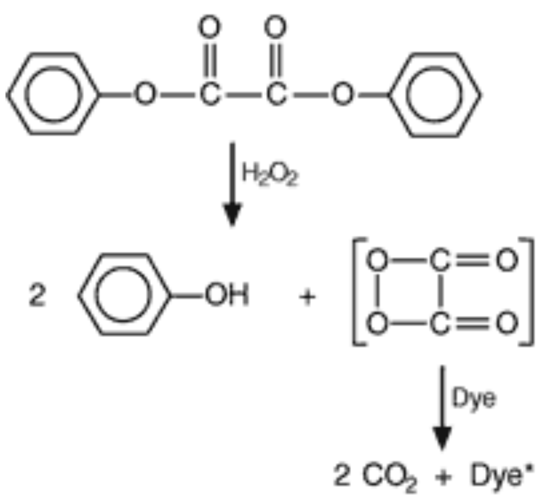
Background:

Many chemical reactions produce heat and light, think of a burning match or any type of explosion. It is much less common for a chemical reaction to produce light without heat. This type of reaction is called a chemiluminescent reaction. If you have seen a firefly light up at night you have observed a chemiluminescent reaction in a living organism that is referred to as bioluminescence.

Chemiluminescence is the production of electromagnetic radiation as light by the release of energy from a chemical reaction. These reactions produce unstable products that decay and form more stable products and energy in the form of light. Most often the light is visible light. What makes radiation visible is its range of frequencies. Energy excites electrons in atoms, which go up in energy levels, and when the electrons go back down to a lower energy level they release particles of light called photons.

Chemiluminescent reactions usually involve the relatively easy breaking of the bond between two oxygen atoms in a peroxide molecule that produces a lot of energy. The most common reaction in toys like a glow stick is between Cyalume and hydrogen peroxide. This reaction initially produces an unstable product that decomposes into carbon dioxide and energy that is given to the dye molecule. The dye molecule than fluoresces.

The following diagram shows the reaction:



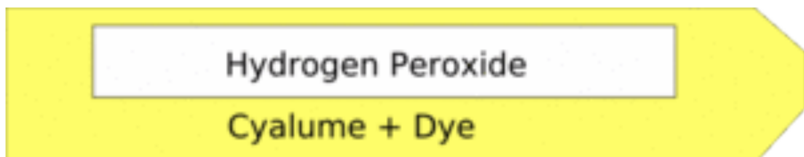
A glow stick is made up of two tubes, one inside the other. The inner tube contains the

Figure 4 (cont'd)

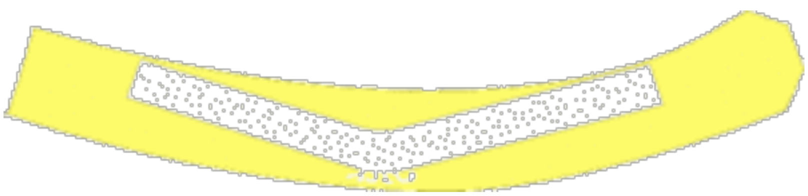
hydrogen peroxide and the outer one the Cyalume and a dye. Different colored glow sticks contain different dyes. When the outer tube is bent it breaks the inner tube and the two chemicals combine and react. The energy that is released is taken up by the dye that releases the energy in the form of light.

Why does it happen?

A glow stick is made up of two plastic tubes, the inner one is filled with hydrogen peroxide (this is a bleach that is often used on hair) and in the outer one is a chemical called Cyalume and a dye. If you want a different colored glow stick you use a different colored dye.



The inner tube is quite brittle and when you bend the outer tube the inner one snaps letting the two liquids mix together



Where they mix the Hydrogen Peroxide reacts with the Cyalume producing an unstable molecule with loads of energy. If this collides with some dye the molecule breaks down into carbon dioxide and transfers its energy to the dye, which then releases the energy as light. The more often this happens the brighter the light is.

The beautiful glowing swirls when you cracked the glow stick were where the two liquids were slowly mixing together.

Why does it go dim when it gets cold?

If anything is hot it means that the molecules have lots of energy, which means that they are moving very fast so they hit each other more often and when they do collide there is plenty of energy to allow them to react.

APPENDIX I

Acids and Bases

Table 4: Acids and Bases

Acids and Bases

Background:

Acids and bases make up one of the most important classes of chemical compounds. They are considered opposites in character but are related in their ability to neutralize each other. One definition of an acid is that it yields a hydrogen ion, H^+, or more correctly a hydronium ion H_3O^+ when dissolved in water. A base may be defined as a substance that yields a hydroxide ion, OH^-. Neutralization occurs when the H^+ ion and the OH^- combine to form water, H_2O.

These acids generally have the following properties:

- Sour taste
- Change color in the presence of an indicator
- React with metals to produce hydrogen gas, H_2
- React with oxides and hydroxides to produce a salt and water
- Aqueous solutions conduct electricity
- They are electrolytes (contain ions)

These bases generally have the following properties:

- Bitter taste
- Change color in an indicator
- Neutralize acids forming a salt and water
- Aqueous solutions conduct electricity
- They are electrolytes

Examples

Formation of hydrochloric acid: $H_2 + Cl_2 \rightarrow HCl$
Formation of carbonic acid: $CO_2 + H_2O \rightarrow H_2CO_3$
Reaction of an acid and a metal: $2HCl + Zn \rightarrow ZnCl_2 + H_2$
Formation of the base calcium hydroxide: $Ca + 2H_2O \rightarrow Ca(OH)_2 + H_2$
Neutralization: $HCl + NaOH \rightarrow NaCl + H_2O$

pH is a measure of the concentration of the hydrogen ion on a logarithmic scale. Certain organic substances change color based on the hydrogen ion concentration. These substances are called acid-base indicators and are used to determine the pH of a solution. The pH scale ranges from 0-14. The higher the hydrogen ion concentration the lower the pH value. Acids have a pH less than 7, bases have a pH greater than 7 and a neutral solution has a pH of 7. Litmus paper, phenolphthalein and universal indicator are common acid-base indicators.

Table 4 (cont'd)
Procedure:

For each indicator bar use the table below and colored pencils to show the appropriate indicator response for each pH

pH	Litmus	Universal Indicator	Phenolphthalein
0-2	Red	Red	colorless
3-4	Red	Orange	colorless
5-6	Red	Yellow	colorless
7		Yellow-Green	colorless
8	Blue	Yellow-Green	colorless
9	Blue	Aqua blue	pale Pink
10-11	Blue	Violet blue	Fuchsia
12	Blue	Violet blue	Fuchsia
13-14	Blue	Purple	Fuchsia

Litmus

0-2 3-4 5-6 7 8 9 10-11 12 13-14

Universal Indicator

0-2 3-4 5-6 7 8 9 10-11 12 13-14

Phenolphthalein

0-2 3-4 5-6 7 8 9 10-11 12 13-14

Spray a paper with universal indicator. Label the paper with each of the following:
Sodium hydroxide
Ammonia
Baking soda solution
Coffee
Vinegar
Lemon juice
Hydrochloric acid

Table 4 (cont'd)
Place a few drops of each next to each label.
Complete the data table below:

Name	Color	pH	Acid or Base

Obtain each of the unknowns and test each to determine the pH.

Number	Color	pH	Acid or Base

Using any solutions of your choosing make a design on a sheet of tissue paper. Spray your design with the universal indicator.

APPENDIX J

Quizzes

The Chemistry of Art Name________________________
Quiz I

1. Identify the following as a physical or chemical change:
    a. Silver melting
    b. Water condensing
    c. Iron rusting
    d. A cake baking

2. Identify a chemical and physical change that may occur to a tree.

3. What are the four indications that a chemical change has taken place?

4. Identify the following as an element or a compound:
    a. $NaCl$
    b. $NaHCO_3$
    c. Ag
    d. C

5. Distinguish between an element and a compound.

6. Identify the following as a substance or a mixture.
    a. Sugar
    b. Salt water
    c. Air
    d. Helium

7. Distinguish between a substance and a mixture.

8. Give an example of a homogenous and heterogeneous mixture.

9. Name a mixture and describe how it could be separated.

The Chemistry of Art   Name ____________________
Quiz II

1. Define an atom

2. Complete the chart

Particle Name	Relative Charge	Relative Mass	Location

3. How can an atom contain charged particles and still be neutral?

4. What holds electrons within the atom?

5. An atom of Silicon with the atomic number of 14 has an atomic mass number of 29. Determine the number of

   a. Protons

   b. Electrons

   c. Neutrons

6. Atoms may form positive and negative ions. Describe what occurs when each type of ion is formed.

7. E.C. A positive ion is called a(n) _____________________ and a negative ion is called a(n) ________________.

8. In the reaction Na + Cl → Na^{+1} + Cl^{-1} which atom gained electrons and which atom lost electrons?

9. For the atom below

   a. Identify the atom

   b. Is the atom more likely to gain or lose electrons? Explain

Chemistry of Art — Name ____________________

Quiz III

1. An element has similar properties as sodium and lithium with an atomic number greater than argon but less than Krypton. Use the periodic table to identify the object.

2. Why do elements in the same group have similar properties?

3. Use the periodic table to identify each of the following as a representative element, transition element, an inner transition element or a noble gas:
   a. iron
   b. thorium
   c. neon
   d. lithium
   e. phosphorus

4. A formula unit of magnesium fluoride has 2 fluoride ions corresponding to each magnesium ion in the compound. What is the formula?

5. The melting point of water is much lower than the melting point of salt. Which is the ionic compound and how do you know?

6. A dozen is 12; a gross is 144, what is the value of the mole?

7. What is the molar mass of $MgCl_2$?

8. How many moles of gold atoms are in 196.97 grams of gold?

The Chemistry of Art Name ____________________
Quiz IV

1. Determine the charge on each of the following as an ion.
   a. K
   b. Br
   c. Ca
   d. O
   e. Al
   f. N

2. Name each of the following ionic compounds
   a. CaO

   b. KCL

3. Write the formula for each of the following covalent compounds
   a. carbon tetrachloride

   b. dinitrogen monoxide

4. Write the formula for each of the following ionic compounds
   a. magnesium bromide

   b. rubidium oxide

5. Name each of the following covalent compounds
   a. SO_2

   b. CCl_4

6. Identify each of the following reactions as synthesis, decomposition, single replacement, double replacement or combustion

   a. $2KCl + F_2 \rightarrow 2KF + Cl_2$

   b. $4Fe + 3O_2 \rightarrow 2Fe_2O_3$

   c. $2H_2O \rightarrow 2H_2 + O_2$

   d. $NaOH + HCl \rightarrow NaCl + H_2O$

7. In the reaction $2Mg + O_2 \rightarrow 2MgO$ identify the reactant(s) and product(s).

The Chemistry of Art
Quiz V
Acids and Bases

Name ______________________

Fill in the blank to correctly complete the statement.

1. The pH scale ranges from _____________ to ______________.

2. A(n) __________ has a pH less than 7.

3. A(n) __________ has a pH grater than 7.

4. Name two properties of an acid.

5. Name two properties of a base.

6. What are the products of the reaction between an acid and a base?

7. Why do acids and bases conduct electricity when dissolved in water?

APPENDIX K

Student Survey on *The Chemistry of Art* Activities

Table 5: Survey

The Chemistry of Art **Name** ____________________

Survey

Activity Rating

In the table below rate each of the activities on a scale from 1-5 with 1 being low and 5 being high using the following criteria:

Collaboration: Did you work cooperatively with others? Was the activity structured in a way that made you work together? Did you actively participate?

Thinking: Did you find yourself really thinking through the process as you performed the activity? How mentally engaging was this activity?

Interest: How interesting did you find the activity? Did you enjoy it?

Learning: How much did you learn from the activity? Did the activity help model the topic in a way that helped you learn?

Activity	**Collaboration**	**Thinking**	**Interest**	**Learning**
Painting a Fresco				
Corrosion on Bronze				
Chromatography				
Henna				
Silver Nitrate & Copper				
UV Blueprint				
Chalk Drawing				
Model of the Periodic Table				
Acids and Bases				
Cool Lights				

APPENDIX L

Assent/Consent Form

PARENTAL CONSENT AND STUDENT ASSENT FORM

Dear Student and Parent/Guardian:

I am a master's degree student at Michigan State University conducting research for my thesis. I would like to invite you to participate in this research project. Researchers are required to provide a consent form to inform you about the study, to let you know that participation is voluntary, and to explain the risks and benefits of participation so that you can make an informed decision.

Purpose of the research: I have developed a unit on teaching chemistry that incorporates art. Students will learn chemistry concepts that can then be used to create a piece of art, and how the process of creating art can be explained using chemistry concepts. I plan to study the results of this teaching approach on student comprehension. The results of this study will contribute to my understanding about the best practices in teaching science. Completion of this research will help me earn my master's degree in MSU's College of Natural Science.

What students will do: As with any unit of instruction students will participate in the unit Chemistry in Art, completing assignments, laboratory assignments, activities, pretest and posttest. Participation in this research will not increase or decrease the amount of work that students do. I will make copies of students' work and use only those that have agreed to participate in my research analysis. This project will take place during the Spring Semester, May-June of 2013.

Potential Benefits: The purpose of this research is to learn more about alternative methods of teaching science. Analyzing the data from students' progress will inform me about the effectiveness of this method. If it is successful I can apply it to other classes. Students' will benefit by experiencing a well-researched unit of instruction and better learning.

Potential Risks: There are no foreseeable risks to students in participating in this unit. I will not know who has agreed to participate during the class. The completed consent forms will be kept in the office. I will not open these until after the class has ended and I have assigned grades. I will analyze the work only for those students who agreed to participate and whose parent/guardian have consented.

Privacy and confidentiality: Information about the participants will be protected to the maximum extent allowable by the law. Students' names will not be reported in any documentation. The data will consist of class averages and samples of work without names. During the study data will be protected by password-protected computers and locked files. After analysis any copies of students' work will be destroyed. The only people that will have access to the data are me, my thesis committee at MSU and the Institutional Review Board at MSU. This data will be locked in a file in Dr. Heideman's locked office for at least three years after the study.

Your rights: Participation in this research is completely voluntary. You may say "no" and may withdraw at any time. There will be no penalty in saying "no" or from withdrawing at any time. I will not know who agreed to participate until after all work has been evaluated and grades have been entered for the class.

Questions and concerns: If you have questions or concerns about this study please feel free to contact any of the following:

Researcher/teacher: Ms. Laura Rainey
lrainey@geneseeisd.org
810-232-8530
Principle: Dr. Chery Wagonlander
cwagonla@geneseeisd.org
810-232-8530
MSU Advisor: Dr. Merle Heidemann
heidema2@msu.edu
517-423-2152 Ext. 107

You may also contact, anonymously if you wish, the Michigan State University's Human Research Protection Program office

irb@msu.edu
517-355-2180
fax 517-432-4503

Submitting this Form: Please complete the form below. Both the student and the parent/guardian must sign the form. Return the sealed envelope with the enclosed form to the main office.

Student Name________________________

Please check all that apply:

________ I agree to allow my student to participate in this research project. All data shall remain confidential.

________ I choose not to allow my student to participate in this research project. My student's work will be graded in the same manner regardless of their participation.

________ I give permission for photos of my student and/or their work to be used in this thesis project. My student will not be identified.

________ I do not wish to have my student's image used at any time during this thesis project.

Parent/Guardian Signature ________________________________ Date ____________

________ I voluntarily agree to participate in this thesis project.

Student Signature ______________________________________ Date ______________

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