TEACHING CHEMISTRY OF COLOR AND INK TO AT-RISK HIGH SCHOOL STUDENTS THROUGH THE USE OF LABORATORY INVESTIGATIONS

By

Laura Vickery

A THESIS

Submitted to
Michigan State University
in partial fulfillment of the requirements
for the degree of

MASTER OF SCIENCE

Department of Science and Mathematics Education

2004

ABSTRACT

TEACHING CHEMISTRY OF COLOR AND INK TO AT-RISK HIGH SCHOOL STUDENTS THROUGH THE USE OF LABORATORY INVESTIGATIONS

By

Laura Vickery

Teaching chemistry concepts to at-risk students in an alternative high school program provides challenges that have to be met. The students need hands-on activities and lab involvement that is pertinent to their lives. They also need a means to understand abstract concepts. By developing and teaching a course on the "Chemistry of Color", I planned to document the students' learning by assessing their performance as they studied various techniques used in the field of chemistry. Specific topics included: mineral composition, chromatography, color saturation, pressure, preparation of pigments and inks, solubility, pH, measurements, spectroscopy, acid/base reactions, bonding and the manufacturing of ink. The effectiveness of these topics were evaluated through pretest and posttests, lab performances and class participation in order to measure the students' understanding of concepts.

This thesis is dedicated to my students, both present and future, who challenge me to develop lesson plans that encourage them to learn the values of science in their own, unique way.

ACKNOWLEDGEMENTS

I would like to thank Don Vickery, my husband, best friend and father of my children, for all his infinite patience, encouragement and support. I spent countless hours on the computer and in the classroom to further my educational goals and he held down the fort, learned how to cook , clean and wrangled the dogs. These are gifts of love that I will hold dear to my heart forever.

My research would not be what it is without the help and support of Marty Sexton, my brother-in-law, who secured the visitation to Sanford Corporation and welcomed me into his professional world without reserve. This allowed me the opportunity to job-shadow research chemists as they performed their daily tasks. It was a symbiotic relationship where I was able to learn so much that could be adapted to the classroom and the research chemists learned a bit more about Marty.

I would also like to thank Sue Doneson, my friend and colleague, who encouraged me to write and provided valuable critique and support. Without her help, I would not have expanded my awareness of the written language and my free-thinking would have gone beyond the languages' self-imposed limits.

PREFACE

Working with at-risk high school students in an alternative education program provides many opportunities to develop new courses in an effort to tap the interest of our varied learners. These students generally avoid higher-level science classes because of a lack of confidence or a lack of motivation, a result of past failures in their science education in traditional learning environments. The six-week "Chemistry of Color" course is geared toward at-risk, disadvantaged students who learn well with hands-on activities. It encourages many bright and creative individuals to experience a chemistry course with practical uses. Upon completion of the course, students will be aware of positions open to employees with science-based backgrounds. These would include career opportunities to work with pigments and color to offer a variety of products to consumers.

Over the six weeks of the course, the chemistry students are required to analyze information and perform labs that continue to develop their understanding of where color comes from and how it is used in everyday life. I start with a brief history on how color is extracted from minerals and plants within the earth and how our eyes adjust to color in the visible spectrum of the electromagnetic spectrum. Once they make a connection between light and color, they would learn about the transition elements and their capacity to show color. Students should be able to understand the arrangement of elements on the periodic table, know the placement of the *d* orbitals and learn to name a few compounds that exhibit characteristics of color. Natural-colored pigments as well as chemically manipulated pigments are studied in order to develop inks and paints. Mixing chemicals and evaporating water to produce pigments will result in a wide variety of colors. The students should learn about the separation of color through chromatography, color solubility and acid/base chemistry. Titrations, indicators and pH will be studied through lab exercises.

The students should also learn about industry's need for chemists to develop color in a variety of ways. In particular, they are required to compare products from different manufacturers to assess the quality and longevity of the colors. For example, they test Sanford Corporation products by measuring the amount of ink used between the *Expo*™ dry-erase markers, the *Sharpie*™ markers, *Papermate*™ pens and *Colorific*™ products. Labs include measuring the amount of ink used in writing messages, computer-generated graphing exercises using Excel spreadsheets, acid/base testing on color-changing markers and applying pressure in a vacuum chamber to reservoir markers to simulate high altitude conditions on pens. Reservoir saturation and capillary action of markers should be understood through visually manipulating marker parts. Students' math skills, statistical analysis, measurement techniques, computer skills and writing should all be enhanced through participation in this course as they integrate information that requires them to use their critical thinking skills in order to solve problems in the class. With this approach, I believe their chemistry and science knowledge will also increase.

TABLE OF CONTENTS

Table of Contents (cont'd)

LIST OF TABLES

LIST OF FIGURES

INTRODUCTION

Meridian High School in Haslett, MI is an alternative education program that serves Haslett, Okemos, Bath and East Lansing schools. It is also a "school of choice" for students from Williamston, Perry, Holt and Lansing. Students who attend Meridian High have left the traditional high school setting because the system was not able to serve them in the way they needed for success. The students are considered at-risk. The basic characteristics of an "at-risk" student may include one or more of the following: (Meridian High School Staff Handbook, 2003-2004)

- Student history of drug and/or alcohol abuse
- Truancy
- Pregnancy and/or teen mother
- On probation or has been incarcerated
- Academic remediation
- Discipline problems
- Poor self-esteem
- Parents lack of high school education
- Low family income

The school has 130 full time students and eleven classroom teachers. The demographics from the last count (February, 2004) are typical of the student population we serve. Many students are enrolled for their entire high school career and many others filter in throughout their high school educational years. Thirteen students are African-American, five are Hispanic, two are American Indian and one is Asian. The rest are Caucasian. Thirty-five students are teen parents. Of these teen parents, almost 95% have been physically abused, sexually abused, or both. Twenty-nine students are designated for Special Education caseload. There are approximately thirty students who are progressing toward graduation in June of 2004 and another twenty who are GED candidates. Seventeen students are required to be in school by truancy law, while another ten are close to the Michigan age limit that requires them to finish school by September 1st of the school year they turn twenty. There are twelve students who have completed or are currently active in treatment programs for drug or alcohol addictions. Thirteen are on probation for a variety of criminal offenses. There are also thirty-three who take prescription medications for ADHD, depression or other serious mental illnesses. Of the 130 students at Meridian High School, sixty-five qualify for free or reduced lunch and the on-site nursery also feeds twenty-four infants and toddlers on a regular basis from the free-lunch program.

Meridian High School also has between ten and fifteen students who have been labeled as "gifted or talented" in the past, but ended up at Meridian because the traditional setting was not able to provide the type of atmosphere/coursework to challenge them. The students developed an underachieving attitude and needed coursework that was creative and challenging. For example, Robert DeBruyn (2002) writes:

> Creativity sprouts and grows more in diversity and divergent thinking than in conformity and uniformity. Therefore, nurture a healthy level of diversity in student discussions and interactions. Help students experience the value of uniqueness. Also encourage students to dream occasionally and make it safe for them to take risks in their thinking and in their work.

Meridian High is the only high school in Ingham County with a licensed nursery for teen parents. Currently, there are thirty-five teen parents who use the nursery to provide childcare for their infants and toddlers while they finish their educations. The school also has a full time special education teacher/consultant, a full time social worker and many other support staff to help things run smoothly. In order to obtain a diploma from Meridian, students need to have twenty-two credits. Requirements include: (Haslett Public Schools Graduation Requirements, 2004)

- 3 ½ credits in English to include ¼ credit in Speech
- 2 credits in Math
- 2 credits in Science
- 1 credit in Art or Humanities
- 3 credits in Social Studies including U.S. History, Geography, Economics and Government
- ½ credit in Life Skills
- 1 credit in Physical Education/Health
- ½ credit in Careers (career related courses or Co-op)
- 8 ½ elective credits

Most students enter Meridian with some high school credit, but they are generally a semester or two behind in their work from the traditional high school. Others come to Meridian too far behind on their credits and are offered the opportunity to take classes in preparation for their general education diploma (GED) test. All students are assigned a mentor teacher and meet with the mentor twice a week to discuss progress toward graduation/testing for the GED. Each student is aware of the requirements and most know how many credits they have and what they need to graduate. They must show progress toward success and are offered a venue for voicing complaints or concerns. The mentor teacher acts as an advocate for the students, schedules their new classes and consults with the other teachers, parents and staff to help the students achieve success.

Teaching to a "one size fits all" group of students with an emphasis on passing the state mandated tests and information gathering for future use does little for the at-risk student. The literature cited by Roland Barth (2001) sums up the constant, comparative scrutiny of the teachers, schools, district, state and nation.

> The current wave of "accountability" and "standards" has been widely translated into standardization, tests, and scores. Increasingly, the feeling in schools is that everything must be sacrificed upon the altar of the standardized test.

The "feeder" high schools "clean house" of their poorly achieving students prior to the Michigan Education Assessment Program (MEAP's). The special education students who would benefit from Meridian as well as the underachievers are recommended for the alternative program in an effort to boost the accountability of the traditional schools. The alternative students have a grasp of their world in the here and now and do not value accountability, scrutiny, raising test scores for the school, countless hours of homework, math story problems and information that might not ever be useful in their lives. But, in spite of all this, we also administer the MEAP standardized test to students in the spring of their junior year and are proud to say that Meridian has the highest test scores for any alternative high school in the tri-county area (see Table 1). The students who show proficiency in science are also showing a steady increase from year to year in the number of students who are meeting or exceeding state standards (see Figure 1). In my six years of teaching at Meridian, scores have continued to rise across all disciplines and many of our graduates qualify for the $2500 scholarship money by successfully passing all areas on the test (see Figure 2).

MEAP High School Scores

The following is a breakdown of Michigan Assessment Program high school scores for local school districts. The percentages are for those who met or exceeded standards.

(*= n/a) ***italic and bold = Alternative school*** ***italic, bold and underlined = Meridian High***

	Reading	Writing	Math		Science		Social Studies	
	2003	2003	2002	2003	2002	2003	2002	2003
Bath High School	59.5	58.4	86.8	56.4	61.8	57.0	24.5	26.3
Charlotte Alternative Education	*	*	***14.3***	*	*	*	*	*
Charlotte Senior High School	74.9	68.8	77.5	67.0	63.1	66.7	26.8	34.6
Dansville High School	69.8	57.4	84.5	65.1	71.9	64.5	41.4	25.0
DeWitt High School	78.9	74.5	85.5	75.4	81.9	80.9	47.2	41.2
East Lansing High School	84.5	77.9	80.8	80.1	76.2	80.1	50.4	46.0
Eaton Rapids Adult/Alt. Ed	*	*	***50.0***	*	***42.9***	*	*	*
Eaton Rapids Senior High School	66.8	56.1	61.9	57.0	54.5	58.5	18.3	24.3
Fowler High School	87.0	84.8	94.1	80.4	82.4	76.6	35.3	32.6
Fowlerville Community Education	*	*	***80.0***	*	***60.0***	*	*	*
Fowlerville High School	72.4	55.3	66.7	60.8	60.5	65.0	14.4	19.5
Parkers Corner (Fowlerville)	*	*	***70.0***	*	***20.0***	*	*	*
Grand Ledge High School	79.1	73.0	80.1	79.8	74.6	76.4	31.3	37.9
Sawdon High School (Grand Ledge)	*	*	***40.0***	*	***40.0***	*	*	*
Haslett Alternative Education (Meridian)	***50.0***	***55.6***	***50.0***	***39.1***	***40.0***	***47.8***	***6.3***	***17.6***
Haslett High School	84.5	73.1	86.6	81.3	79.3	80.6	36.2	40.0
Holt Central High School	***31.6***	***9.1***	***33.3***	***23.8***	***20.0***	***18.2***	***16.7***	*
Holt Senior High School	66.4	56.9	76.8	63.5	70.6	67.7	29.7	33.2

Table 1: (cont'd)

	Reading	Writing	Math		Science		Social Studies	
	2003	2003	2002	2003	2002	2003	2002	2003
Douglas R. Welch (Ionia)	***25.0***	***11.8***	*	***18.9***	***25.0***	***19.4***	***11.1***	***10.5***
Ionia High School	64.2	51.7	73.7	60.1	68.0	59.2	36.4	25.6
Laingsburg High School	72.8	58.9	78.6	61.5	67.9	66.7	23.5	33.7
Lansing Public School District	62.9	58.3	52.0	49.4	41.0	50.1	15.0	24.1
Eastern High School	66.3	62.8	54.5	58.5	45.3	58.5	19.8	32.1
Everett High School	61.1	65.8	51.6	43.3	39.8	44.2	9.4	12.4
J.W. Sexton High School	64.4	45.8	51.5	51.0	38.3	50.3	14.2	30.4
Lansing Continuing Educ Center	***36.8***	***40.0***	***35.7***	***21.7***	***41.7***	***40.0***	***36.4***	***22.7***
Leslie High School	57.7	43.9	64.9	49.0	55.7	52.1	18.9	17.7
Maple Valley Jr/Sr High School	64.1	60.6	80.6	60.4	61.3	62.9	23.2	17.0
Mason High School	77.4	70.3	82.9	80.7	76.3	77.5	25.1	29.3
Okemos High School	91.9	90.1	93.1	92.7	90.0	91.5	55.5	61.9
Ovid-Elsie Comm. Ed/ Alt. H.S.	***20.0***	***13.3***	***17.6***	***20.0***	***12.5***	***31.3***	*	*
Ovid-Elsie High School	74.8	72.4	68.0	68.2	43.8	66.0	9.4	26.5
Perry High School	65.7	70.8	68.9	66.7	55.5	64.2	17.9	18.1
Pewamo-Westphalia High School	95.3	93.8	81.1	87.7	75.3	85.9	26.0	30.6
Portland High School	69.6	63.7	81.1	68.0	66.9	71.2	27.3	20.0
NEC Adult And Alt. Ed (Potterville)	*	*	***50.0***	*	***46.2***	*	***16.7***	*
Potterville High School	77.6	53.1	67.3	45.7	55.1	48.9	14.3	25.5
St Johns High School	72.8	69.8	79.9	69.7	70.1	71.4	15.8	31.8
Wilson Center (St Johns)	***27.8***	***11.1***	***25.0***	***22.2***	***37.5***	***36.8***	***6.3***	***11.1***
Stockbridge High School	61.0	56.4	69.4	59.3	61.6	57.0	23.6	13.4
Waverly Senior High School	77.8	67.3	74.0	75.7	66.1	74.3	17.2	33.3
Webberville Middle/High School	64.6	44.9	55.4	50.0	56.4	64.6	20.0	26.1
Williamston High School	79.7	82.0	78.5	71.9	69.4	78.1	29.8	24.3
Walter French Academy	***40.0***	***21.1***	***27.7***	***35.7***	***27.1***	*	***7.5***	***19.4***

Source: Michigan Department of Treasury and Lansing State Journal

Figure 1: Meridian Science MEAP Five-Year Trends.

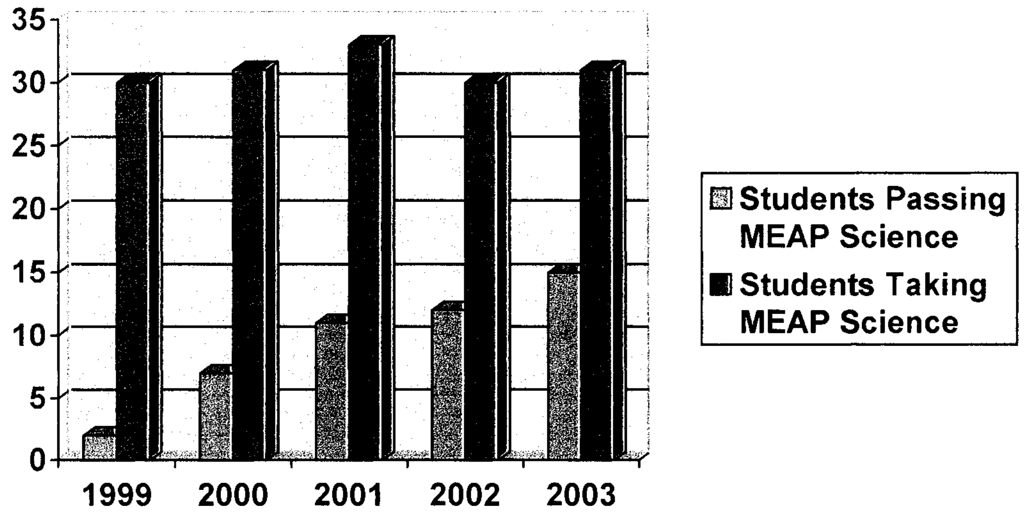
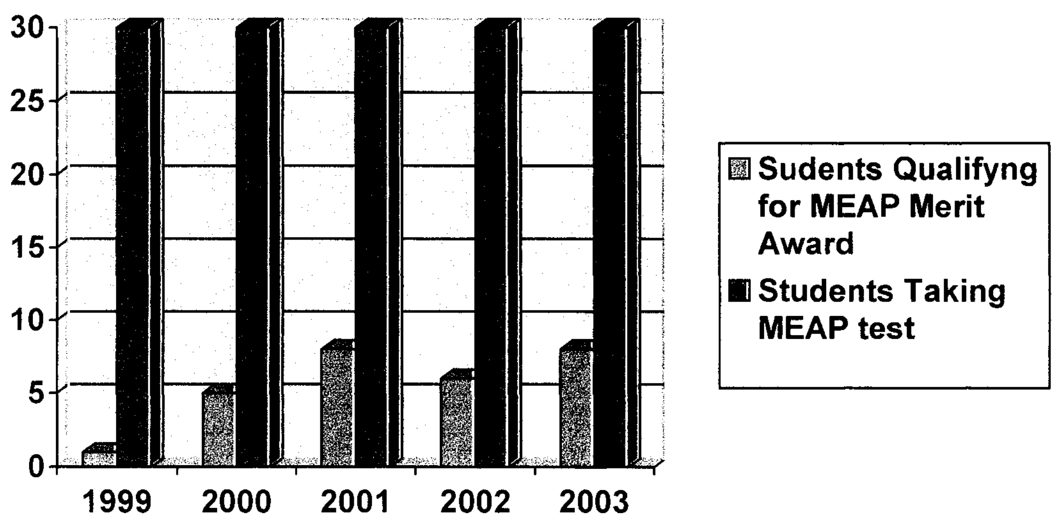


Figure 2: Meridian Students Qualifying for MEAP Merit Scholarships.



In 2003, Meridian also attained North Central Accreditation for a special purpose school. The school is currently undergoing construction of a new nursery, new classrooms and extensive remodeling that will benefit our student population. While other alternative education programs in the area feel the need to cut services due to budget constraints, Meridian strives to provide a quality education for the students and realizes that a commitment from the taxpayers, teachers and administrators is essential in helping the at-risk youth in our area. Meridian High School...*A Powerful Learning Community!* has a mission statement and values that are student-centered and encourage students to believe in themselves. We also believe trusting relationships and thoughtful boundaries are key to everyone's successful learning in a learning community that recognizes and respects cultural, intellectual and social differences. Roland Barth (2001) wrote:

> Teachers who assume responsibility for something they care desperately about stand at the gate of profound learning.

Along with mentoring twelve students, it is my job at Meridian to teach a variety of science courses throughout the school year. I currently teach Chemistry, Biology, Earth Science, Environmental Science, Forensic Science and Anatomy at varying times of the year with three preps a day. Courses are divided into six-week segments and named appropriately so students have an understanding of the commitment they are making for the duration of the class. My chemistry curriculum was originally divided into six-week courses that parallel with the curriculum from the traditional high school entitled:

1. Introductory Chemistry
2. Chemical Bonding
3. Chemical Reactions
4. Stoichiometry

The curriculum offers a full year of chemistry in four terms. The standard Chemistry curriculum does a minimal job of covering color. There are less than ten references to color chemistry in the textbook currently available for my classroom use, Modern Chemistry by Holt Rinehart and Winston, with the majority of coverage being in the acid/base chapter on titration and pH. J W Moore (2001) states:

> In teaching science, we need to remember that communication always benefits from imagination and esthetic sense. If we present science artistically and imaginatively, as well as objectively and precisely, students will develop a more complete understanding of what science and scientists are about—one that is likely to capture their imaginations, emotions and best efforts.

We offer all Meridian classes with a hands-on approach and smaller class sizes so students can get individual help when needed. Each term, the students are able to pick new classes with the advice of the mentor and complete their education either by taking classes in a consecutive sequence which is the preferable method of taking classes or on a "drop in" the class fashion by opting out of a specific subject for individual terms. For example, many science students will take my class and do well for the first term, but opt out of science the next term because the demands of science are not what they are looking for, but will opt back in on a different term. We do not require the students to take a series of classes in order to earn the semester credit. They pick up a quarter credit each term they are successful in passing the class. Many of our students are science-phobic and put off taking it seriously until they are in the upper grades of high school. Because of the way it is structured for the population we serve, I am forced to offer stand-alone classes with minimal prerequisites. Theoretically, students can enter any term, but the chemistry courses need teacher approval before new students are accepted. Chemistry is considered one of Meridian's most challenging courses and it is a prerequisite to taking the highly sought after forensic science class that is offered second semester.

In an effort to challenge these unique and diverse students, I have developed a "Chemistry of Color" course to tie in with an "art in science" theme for a quarter credit. The "Chemistry of Color" course was offered to students who had completed the introductory chemistry term that covered an understanding of the periodic table, chemical symbols, orbital notation and a few other basic chemical principles. It encouraged many non-traditional students to experience a chemistry course with practical uses because they generally avoid higher-leveled science classes. This seemed to stem from the traditional learning environment where they had met with failure in the past. The students' lack of confidence or lack of motivation becomes overshadowed when they are presented with science lessons in a fun and interesting way. According to Robert DeBruyn (2002), "Research has shown repeatedly that high-quality, developmentally appropriate learning opportunities for children can pay rich and lasting dividends."

In order to be effective in the alternative education classroom, I employ teaching strategies that empower the students to actively participate through hands-on interactions. The students need variety and an opportunity to showcase their understanding through the use of visual, tactile, kinesthetic and auditory activities. An article for the National Education Association written by Judy Brown Lehr (1988) sates:

> Effective teachers use a variety of materials and strategies to keep their [students] interest. They structure the learning tasks in small sequential steps. By experiencing success, at-risk students can be motivated to learn. Classrooms that increase the likelihood of students' learning and retaining concepts are information processing as opposed to information receiving. That is, after teachers present the facts, students become involved in their learning with hands-on experiences. The more actively involved low achievers become in their learning, the greater the likelihood that it will have meaning, retention and transfer.

In order to recruit students to the chemistry class, I have to fight an uphill battle. Most of the students at Meridian have stories to tell about ineffective teachers in the traditional system. They identify perceived faults in the system that involve heavy homework loads, upper level math requirements for a science course and the inability to transfer concepts to their daily lives. They quickly blame their previous traditional classroom teachers without accepting responsibility for their role in non-conformity and lack of interest in the subject. Their experiences with grade school teachers' lack of science knowledge as well as their secondary teachers pushing heavy homework loads have led to failures in the past. My job becomes a challenge in breaking down old misconceptions about science being hard and success in science courses unattainable for them. Upon entering the system at Meridian, most students refuse to take science classes, but they often are forced to enroll due to lack of earned credit in science despite their desire to avoid it. Luckily, word of mouth from the students who have been at Meridian quickly dispels myths about science classes and new students start poking their heads in the door to see what labs are taking place. I have to convince the students that science is an interesting subject that can be understood. Haim Ginott (1993) most popularly phrased his belief about classroom teachers and their ability to interact with the students.

> I've come to the frightening conclusion that I am the decisive element in the classroom. It's my personal approach that creates the climate. It's my daily mood that makes the weather. As a teacher, I possess a tremendous power to make a child's life miserable or joyous.

The way I am treated by some of the students affirms my belief in statements like this. There are many students who would spend the entire day in my classroom, if they were allowed, taking science elective classes even though they struggle with the concepts and do not perform well. Their backgrounds from previous coursework in science lead me to believe they would not continue their education with any science-based courses beyond their education at Meridian. Even though some do not do well, they readily admit they like my perspective and manner of teaching. There are ample opportunities to learn about the science that is being taught because they come to accept science as interesting and they enjoy the hands-on approach that lends itself nicely to labs.

My demeanor sets the stage for acceptable behaviors and expectations in the classroom. The students need structure to guide them in small, sequential steps that involve them in their own discoveries about science. My research at

Michigan State, my graduate classes and a need for good quality labs for average intelligence and underachieving students keeps my dance card full. I spend countless hours looking for ways to modify labs and classroom instruction to fit the needs of our students. Roland Barth (2001) wrote:

> Most would agree that who the teacher is and what the teacher does within the classroom have a greater influence upon students' accomplishments than any other school factor. There is considerable evidence also, that what the teacher does inside the classroom is directly related to what the teacher does outside of the classroom.

Gone are the days of reading the chapter and answering the questions at the end. Alternative students need bright and creative instruction to keep their interest. According to Clark and Riley (2001), "within the chemistry curriculum, too often the initial excitement seen in the beginning-level students fades when symbols have to be learned or equations balanced." By presenting chemistry concepts in a myriad of ways, the students are able to understand abstract concepts that are pertinent to their lives. It becomes important to select teaching strategies and lessons that address the diverse learning styles of the at-risk students. Larochelle,et al (1998) wrote:

> A socio-cultural perspective on teaching and learning rejects the overly simplistic appeal of a one-size-fits-all approach to enacting curriculum and cautions against technical adherence to rules about what does and does not work in promoting the learning of science.

I break each individual task into daily lessons that are able to address the specific learning needs of the students. When students are exposed to concepts and subjects that are of interest to them, they will rise to the occasion and want to learn more. The curriculum usually is self-contained lessons that start and finish on the same day with a clear transition from day to day. I organize the class in this way because I deal with many students who have legitimate absentee issues such as pregnancy complications, delivery of a baby, incarcerations, general illnesses and also truancy issues that are not excused. Upon returning to the classroom, the students need to fit back in without feeling as if they cannot accomplish the work of the day. Ideally, they should be present for all lessons and labs, but if necessary, individual days could exist as "stand alone" lessons. By organizing labs around central themes of hands-on, every-day science, students benefit from the exposure to topics of their interest. Susan Gingras Fitzell (2001) addresses low-achieving, under-motivated student activities by:

> Simply adapting the format so that it includes clear instructions free of extra verbiage and by adding lines to write the answers to the questions, the student can work on the goal of the assignment rather than be diverted by the difficulty the format presents.

This is especially true in the alternative classroom where I deal with a wide range of intelligences and backgrounds. The students' class standing, background in science and motivation levels need to be accommodated on an individual basis. Many of our students require the help of the resource room teacher and need formats on assignments that are consistent throughout the term. They work hard to complete the assignments only after they feel as if they can be successful in the class. There are many times where the class composition of students includes freshmen with no science credits in the same room with seniors who like science. Reaching a balance where they all are challenged, yet not overwhelmed by the work, is the key to success in recruitment and retention in my classroom. Flexibility in lesson planning and knowing the students' strengths and weaknesses are required of me.

Teaching at Meridian High School has been an experience that I cherish. The students arrive on the doorsteps for a variety of reasons, but they all have the capability of doing good things with their lives. We encourage our students to believe in themselves by treating them with respect, dignity and personal attention. In an exit survey of graduates from Meridian High School in 2002, (Meridian High School Brochure, 2002)

- 100% of the graduates said they would recommend Meridian to upcoming students.
- 87% of the graduates said the teachers hold high standards and demand quality work.
- 100% of the graduates said Meridian is a safe school free from harassment.
- 100% of the graduates said the reason they are successful at Meridian is because the teachers care about their success.

Additionally, other students have been quoted in the brochure to include:

- *Meridian is a school that works if you work with it.*
- *The teachers at Meridian are the kind of teachers that teachers are supposed to be…they care about their work and help you get out of here with a diploma.*
- *After attending Meridian, I have a more open mind about others' differences. Acceptance is important here. The diversity has helped me prepare for my future.*
- *I feel like I finally fit in somewhere.*

We are a unique school that prepares students for the work world as well as college. In the last three years, 72% of our graduates went on to college for additional training. Last year, we graduated thirty students with a regular high school diploma and another fifteen students completed a GED with us. All of these students were not successful in a traditional high school setting, but found what they needed to successfully finish high school at Meridian.

IMPLEMENTATION

I piloted and taught the "Chemistry of Color" course as a quarter-credit class the second marking period of the 2003-2004 school year which started on October 13, 2003 and concluded on November 21, 2003. This allowed for thirty days of classroom instruction totaling forty-five hours. It included connections to mineralogy, physics and chemistry with the biggest emphasis on the chemistry aspect in the course. Students worked at their own pace with the requirements for successful completion of the course outlined in their syllabi along with information concerning attendance policies (see Appendix A-1).

The district implemented a policy in which each teacher was required to complete curriculum maps (see Figure 3) on the content being taught in the classroom. As one of two science teachers within our building, successfully completing the maps helped to solidify the content being studied in my classroom without overlapping curriculum expectations with other subjects/classes in our school. Development of the new course and the district related curriculum map, "Chemistry of Color", enhanced the curriculum for our unique population of students. The various labs for the "Chemistry of Color" course were developed on my own and are unique because they take basic science concepts and apply a theme that is not generally studied within the context that I planned to teach it. When pertinence to the students' lives can be established, there is a greater chance of retention of the information presented.

Figure 3: Curriculum Mapping Cell

Course: **Chemistry of Color**

Building: **Meridian High School**

Teacher: **Laura Vickery**

Essential Questions:

1. How does the weight of small amounts affect the outcome of measurement?
2. How do you convert molecules to mass?
3. How much ink is in a pen?
4. When is a solution saturated?
5. What is the difference between polar and non-polar solvents?
6. What is the purpose of chromatography?
7. How are ink and paint made?
8. What is the difference between acids and bases?

Content:

Measurement & Conversion	Chromatography
Mass and weight	Paper
Moles to mass	Cloth
Molecules to mass	Tie-dye
Solutions	Paints
Saturation points	Pigments
Polar vs. non-polar	Binders
Mixtures	Solvents
Acid-Base Chemistry	Spectroscopy
Titrations	Colored light & the spectrum
Testing pH	Transition elements
Indicators	

Skills:

1. Differentiate between metric and American systems of measuring.
2. Convert moles to mass and molecules to mass
3. Evaluate life expectancy with the amount of ink used in pens in meters.
4. Identify polar and non-polar solvents and formulas.
5. Compare and contrast unsaturated, saturated and supersaturated solutions.
6. Identify the three components in paint and ink.
7. Use indicators to understand acid/base chemistry.
8. Perform a titration to determine the strength of a solution.

Figure 3 (cont'd)

Assessments
Pre-test Labs Lab reports Participation points Post-test
Activities:
Ink Usage Lab Write to Life Lab Mineral Lab Color in a Saturated Solution Lab Solubility Lab Chromatography Lab Tie-dye Lab Developing Pigment Lab Making Ink and Paint Lab Pigment Color and Spectra Lab Cabbage Indicator Lab Acid/Base Titration Lab Acid/Base Indicator Lab Emission Spectroscopy Lab Raspberry Kool-aid Demonstration Pressure/Volume Demonstration Rainbow Connection Demonstration Light Demonstration

Resources:
Modern Chemistry textbook Chemicals Lab equipment Safety equipment Internet access Computer with Excel program Calculators

Each day was devoted to a separate lab/activity for the students (see Table 2). We started each day with a recap of the previous day during which I spent the first ten minutes of class verbally questioning them on the science concepts they were expected to comprehend. By doing so, they were able to focus on previous knowledge that ideally would help set the stage for the new day.

Table 2: Daily Lesson Plans

10-13 Rainbow Connection Demo	10-14 Pre-Evaluation Test	10-15 Color of Gems/Color Vocabulary	10-16 Observing Characteristics of Minerals	10-17 Ink-Usage Lab
10-20 Introduction to Excel™	10-21 Write to Life Lab	10-22 Write to Life Lab (cont.)	10-23 Color in a Saturated Solution Lab	10-24 Pressure Demo/Activity 2.1 Art in Chemistry
10-27 In Service Day	10-28 Bonding/Ionic vs. Covalent & Polar vs. Non-polar	10-29 Solubility Lab	10-30 Pigment Color and Spectra Lab	10-31 Wave Diagram/ Halloween Festivities
11-3 Video Introduction to Pigment & Binders	11-4 Developing Pigment Lab	11-5 Developing Pigment Lab (cont.)	11-6 Making Paint and Ink Lab	11-7 Making Paint and Ink Lab (cont.)
11-10 Making Paint and Ink Lab (cont.)	11-11 Chromatography Lab	11-12 Magic Pitcher Demo/Cabbage Indicator Lab	11-13 Testing Acid Base with Indicators	11-14 Acid/Base Stations
11-17 Tie-Dye Tee Shirts	11-18 Light Demonstration/ Emission Spectroscopy Lab	11-19 Make-Up Day	11-20 Lab Practical	11-21 Post-Evaluation Test

WEEK 1:

The first day of the term is usually devoted to the mechanics of the course. Students who have not been in my class learn about classroom procedures. For the most part, I had already taught the students who took the "Chemistry of Color" course, but I did have five students who were new. Initially, there were fifteen students who signed up for the “Chemistry of Color” course. I was successful in obtaining twelve permission slips from the students to participate in this study. Of the twelve students, one was male and eleven were female. Seven were teen mothers. One student was married and pregnant with her second child. Their class standing included two freshmen, one sophomore, three juniors and five seniors. There was also one student who had been home-schooled and had attended Lansing Community College for two years, but needed to earn a GED diploma in order to further her education beyond the community college level.

After explaining course expectations, I also wanted to welcome them to the course with a chemical demonstration. An acid/base reaction demonstration in order to spark the students’ interest in color went well. The demonstration is called “The Rainbow Connection” (see Appendix A-2). I offered bonus points to anyone who could explain how I was able to produce the various colors in the beakers. This led to some creative thoughts that set the stage for understanding their level of prior chemistry knowledge. No-one was able to give a satisfactory explanation of the activity and perceived it as a magic show.

Once the introductory day was over, I introduced the pre-evaluation test (see Appendix A-3). It is called the “Color of Chemistry Pre-Evaluation Knowledge” and was named in that way as to counter the “test phobia” of many of my alternative students. The students were not happy with the pre-evaluation test so I had to explain that it was a way for me to assess their knowledge before and after the term. They were worried that I was going to award points to the pre-evaluation and it would ultimately hurt their grades in the class. Once I explained that it was not a graded assignment and that it was intended for the research I was doing, all students completed the essay test within five minutes as they didn't see any reason to do the work when it wasn't graded. They basically left any answer they didn't know completely blank. I had to beg and plead with them to get the results I needed. They are not accustomed to this format and readily admitted that it was not the norm for the traditional high school.

I usually start my terms with vocabulary assignments. Students tend to do well looking up vocabulary terms and they are able to use the words in sentences once they have some definitions explained to them. The pre-evaluation convinced me that the vocabulary assignment (see Appendix B-1) was essential for them. This was a nice transition from the insecurity of the pre-evaluation assignment they attempted the previous day. Once the vocabulary assignment was over, they were given a short story/worksheet entitled, The Color of Gems (Harwood, 1988) where they read the story and answered a set of questions that I developed (see Appendix B-2). The questions required the students to extrapolate information from the story and answer questions in an essay format. The story focused in on gemstones, impurities and extracting gems from mines. On Thursday, I showed a PowerPoint™ presentation that I helped develop in the summer of 2002 with a colleague at MSU for the Interdisciplinary Seminar in Physical Science course (NSC 860). It was about the history of color and light and how early color development to produce pigments for paint was made possible, in part, due to the minerals that were extrapolated from the earth. I set up a “Mineral Lab” (see Appendix B-3) where the students observed various minerals that were used to develop natural pigments. They manipulated the minerals in order to identify them based on their physical properties. Hardness, luster and streak tests were performed as they worked their way through the lab. They had to research common uses of each mineral. The lab required both hands-on experience and researching in their textbook in order to answer the post-lab questions with which they were presented.

To round out the first week of class, the students were presented with another PowerPoint™ presentation from an externship I did at Sanford Corporation in the summer of 2003. Spending time in industry and working with research chemists has helped me develop ideas that were expected to be beneficial for the students as they learn, through a hands-on approach, the chemistry behind color. I participated in the teacher externship, job-shadowing chemists from Sanford Corporation and developing eleven quality labs with the theme of color. All of these incorporate a cooperative learning, hands-on approach to facilitate the students’ learning.

Within the context of studying the “Chemistry of Color”, I focused on common materials that the students use regularly. This helped to integrate science into their everyday lives. Showing them another PowerPoint™ presentation from my own externship at Sanford Corporation caused the students to take a closer look at the writing instruments they have been using for years and encouraged them to wonder about how new colors are developed, a necessary component to enhance an already successful business.

In order to study inks, writing and drawing implements had to be classified into various categories. The fountain pen, ballpoint pen and the felt-tipped pens were platforms for learning about capillary action, surface tension, solubility and pressure. The students were able to manipulate Papermate™ pens, Sharpie™ markers, Expo™ dry-erase markers and a host of other common Sanford products as well as Bic™ and Crayola™ products through the labs they performed in the course. They were able to link the Mineral Lab concepts of extrapolating pigments from the earth to a modern, industrial use for color. The "Ink Usage Lab" (see Appendix B-4) was a natural way to capture the students' interest and assess their ability to convert mass to moles and moles to molecules. Measurement activities need to be brought in to the science curriculum so the students have a cross-curriculum base with their math knowledge. This also gave them an opportunity to use the metric system that they had studied in the Introductory Chemistry course.

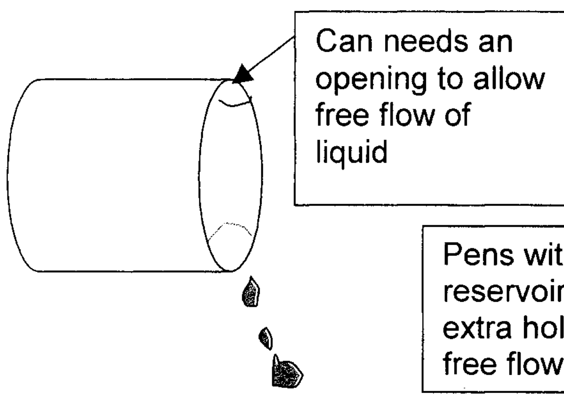
WEEK 2:

The second week of the term brought a three-day assignment that required the use of the computer lab and a basic knowledge of Excel™. I used an entire day introducing Excel™ basics and had the students navigate their way through the program by entering data to graph with their choice of a bar graph, a pie graph or a line graph. I allowed them the freedom of navigating wherever they wanted so I could assess whether I needed to walk them through the lab or whether they could manage on their own. They had to figure out averages from different columns and also deal with a few other statistics in their trial run day. By day two, I had to make sure students who were weak with Excel™ were partnered and sitting near students who were stronger with their computer skills. I did not want to have students giving up on the assignment based on their inability to operate a computer. The" Write To Life Lab" (see Appendix B-5) was planned for two more days in the computer lab. Students saw some ink tracings on a large roll of paper from my externship at Sanford Corp. that showed them the life expectancy of ten Papermate™ pens. Their job was to enter the data that was generated from the ink traces on the roll of paper. They calculated how much ink was used based on the weight of each pen at 200 meter increments on the roll of paper. This was a smooth transition from the Ink Usage Lab as they saw how industry does mass measurements on pens. They determined the average life expectancy in meters and the average amount of ink used in grams to run the pens out of ink. This required a bit of statistical graphing knowledge.

The focus changed to some wet chemistry in the classroom. "Color in a Saturated Solution Lab" (see Appendix B-6) was intended for the students to add solute in small quantities in order to see color intensities and define unsaturated, saturated and supersaturated solutions. Crystallization in a supersaturated solution and saturating a cotton reservoir with ink were highlights of this lab. This led to a discussion on how Sanford Corp. is able to manufacture their markers and pens knowing each pen could be subjected to cold or warm climates, different altitudes with different pressures and yet, they don't leak. The following day, I set up a demonstration to simulate high altitude conditions. The demonstration was performed in a pressure chamber on a Bic™ Liqua Bright

Liner pen that has a liquid reservoir chamber. My overhead transparencies helped to explain the science behind the pens. (see Figure 4 & 5).

Figure 4: Liquid in a Can vs. Liquid in a Pen



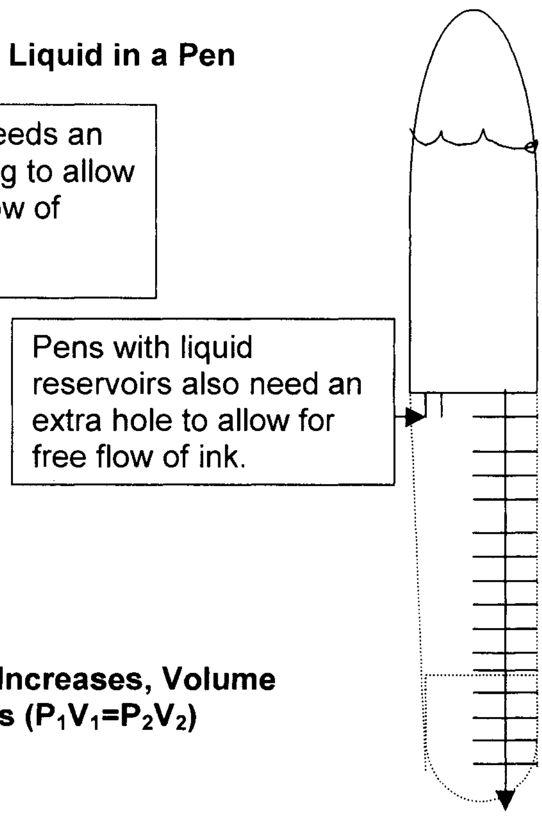
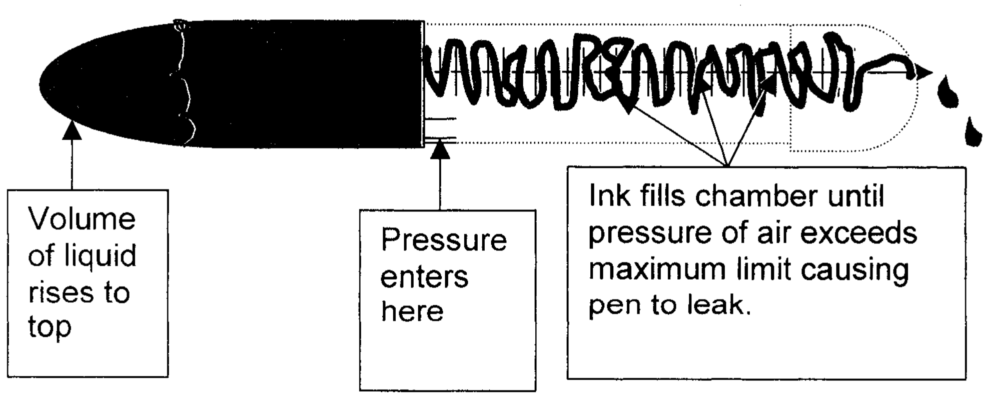


Figure 5: As Pressure of Air Increases, Volume Of Liquid Increases ($P_1V_1=P_2V_2$)



Once I performed the demonstration, the students took a larger interest in pressure and saturations. There were many samples of pens that they were able to manipulate. The popular gel pens and some neon colored pens worked well with this lesson. The students compared altitudes of mountainous regions to the likelihood of leakage and found that the manufacturers account for pressures that are normally found at altitudes of 5550 feet above sea level.

Cooperation between departments also brings a sense of value to the curriculum. I used a lab manual, *Art* in Chemistry; Chemistry in *Art*, written by Barbara Greenberg and Dianne Patterson to supplement my personally developed labs to enhance the curriculum needs at Meridian High School. The students were presented with an activity from this lab manual. The activity required students to experiment with temperature changes and color intensity. They were able to integrate Charles Law relating volume and temperature in an inverse relationship. To end the week, a recap of Boyle's Law and Charles Law was discussed.

WEEK 3:

Week Three began with a review of the concepts that they should have mastered by this point. I introduced polarity of molecules and had the students read about ionic and covalent bonding. I handed out felt circles to simulate atoms. The students manipulated the felt pieces showing ionic and covalent bonding (see Appendix A-4 and A-5).

Once the students understood bonding, I introduced polar and non-polar covalent bonding using the same felt circles with Velcro™ attachments. They were able to visually understand molecules that were more complex deciding if they were polar or non-polar covalently bonded. (see Appendix A-6 and A-7).

This introduced the "Solubility Lab" (see Appendix B-7). The students experimented with a variety of solutes and inks to determine the polarity of each. They classified the inks as washable or permanent by industry standards. In the course of the lab, I was also able to connect with their everyday lives by giving useful household hints on removal of ink stains and other marks with the use of polar solvents like acetone and isopropyl alcohol.

The following day, I supplied the students with the three primary colors of paint in order to complete the "Pigment Color and Spectra Lab" (see Appendix B-8). They were required to develop a subtractive color spectrum with the use of only the three colors. They had to add and subtract color to make their spectra. Once they mastered color matching, I allowed them the use of white paint with the three primary colors in order to match a color from a paint swatch. The students did some comparison to light and the photoelectric effect. They were able to incorporate Plank's constant to interconnect wavelength, frequency and energy to light and color.

On the 31st, my students were released to the gym during class time to carve pumpkins and have a "Babies on Parade" party as a part of a school-wide celebration. When class started, I gave them a wave diagram (Physical Science, 1998). They were required to label the diagram and answer a few questions about waves.

WEEK 4:

On Monday, I showed a video, part of the REMC collection that is on permanent loan to our school, from our library collection entitled, “Color.” The students saw a brief overview on the development of dyes from coal tar and how synthetic dyes were prepared throughout time. They also saw a few experiments using dry ice and some acid/base reactions that I was not able to perform for them that used indicators to show color changes. The video included a few single place reaction formulas from the acid/base demos in order to explain the chemistry behind the color changes. I spent the rest of the class time explaining single place reactions, double placed reactions and synthesis reactions in an effort to set the stage for the “Developing Pigment Lab” (see Appendix B-9) that was ready for them to do. They had two days to develop their pigment and allow for drying time. The students were also shown the reaction equations on the board that explained the chemistry behind the reactions in their test tubes. Students prepared pigments and binders in the formation of paints and inks. By combining chemicals to produce pigment, their chemistry knowledge was enhanced by being able to identify single place reactions, double placed reactions and synthesis reactions.

Once the pigment was developed, the students were required to make ink and paint through the “Making Ink And Paint as a Surface Coating Lab” (see Appendix B-10). This lab was very involved and required good attendance and an ability to integrate materials from the previous lab, “Making Pigment,” in order to be successful. The students enjoyed the challenge and were able to use their creativity in developing an artistic piece of work that was generated from scratch. Once they understood the basic principles of ink manufacturing, a comparison to paints ensued. Inks are similar to paints in that they require a pigment and a binder in order to be effective. They differ in the amount of drying time needed and the surface on which they are generally applied. Liquid inks are generally formulated around water as the bulk fluid. They dry by both absorption and evaporation within a period of five seconds. Although the students were not able to produce the quality of paints or inks that are currently being manufactured, they had many suggestions for improvements of the various media they used to carry the pigment for the paints and inks. Their suggestions were based on the background information they were required to read prior to starting the labs.

WEEK 5:

The class progressed to a "Chromatography Lab" (see Appendix B-11). They manipulated a variety of markers on paper and small swatches of cloth in order to perfect the technique and determine which ones worked best in their experiment. They were presented with a new pair of socks to perform a chromatography design in order to watch the ink separation from permanent markers. They wanted to create a lasting gift from the course and really got creative with their designs.

"Color of Chemistry" cannot be complete without a discussion of acids and bases. I started this section with a demonstration called "The Magic Pitcher" that Dr. David Tanis from GVSU presented at a conference and I repeated in the classroom. The students saw a demonstration similar to this one on the first day of the term called “The Rainbow Connection” and I wanted to revisit their responses from the first day to see if they were using their deductive reasoning skills to comprehend how I was performing the demonstration. This time one of the students responded, “You put something in the bottom of the beaker. We can all see that the stuff comes out clear and changes color when it hits the bottom of the beaker.” At that point, I felt like they were paying closer attention to the demonstration and they were thinking about reasonable explanations to master their understanding. I had the students use their textbooks to read about properties of acids and bases. Their textbook had a Chemical Commentary called, “Logic in the Laboratory” that they reprinted from “Acid and Water: A Socratic Dialogue,” (David Todd, Journal of Chemical Education, 1999). I had the students read the skit in order to acquaint themselves with Hess’s Law. They needed to know why pouring water into an acid is not acceptable. We performed a lab called, “Household Acids and Bases” (Modern Chemistry, 1999). The lab was testing common household products with the use of red cabbage juice as an indicator. They were able to distinguish between acids and bases rather easily. The following day, class started with a comparison between three types of acid/base reactions: Arrhenius acid/bases, Brønsted-Lowry acid/bases and Lewis acid/bases. Students used their textbooks to look up definitions of the acid/base pairs and were able to give information that was textbook quality. I had to bring my lecture to a level of understanding where they could interconnect the differences. In order to compare increases in the concentration of hydrogen/hydroxide ions to proton donors/acceptors, I had to introduce chemical reactions in both aqueous and homogenous solutions that included water as the solvent and others that did not include water. I set up a color range of various indicators (Modern Chemistry, 1999) so the students could see color comparisons between strong acid/strong bases, strong acid/weak bases and weak acid/ strong bases. I demonstrated how to perform a titration so students would be able to perform one in a future lab. They saw the solutions in fifteen different Erlenmeyer flasks change color based on how much vinegar solution, ammonia solution and water I put in each flask. The students were introduced to the concepts of titration, indicators and pH in one demonstration.

The following day, I had a lab, "Acid/Base Reactions" (see Appendix B-12) set up where the students moved to four different stations within the classroom in order to perform a variety of acid/base reactions. The first station questioned Crayola™ color changing markers and the chemistry behind the effect of changing colors. The students were familiar with the markers and complained about the clear marker drying out or getting contaminated quickly after use. Once they saw the effect and understood that a base, like ammonia, was reacting with an indicator in the ink, they took a different look at the chemistry and decided it was a simple idea upon which the company had capitalized.

The second station showed the chemistry behind disappearing ink. The students were required to write a brief message to their parents for parent/teacher night and allow it to dry. They were supposed to explain the chemistry behind the disappearing ink in the message, but they got silly with their messages.

The third station included a step-by-step guide to performing a titration. Most students were not very proficient in their reading of the burets to the nearest 0.01 ml so their accuracy in the experimentation needed refinement. They liked the deeper pink color from the phenolphthalein indicator so the purpose of the titration had to be re-explained and the students had to redo this portion of the lab.

Finally, they did a messy acid/base reaction that was called “Orange Juice to Strawberry Float” (Flinn Chem Fax, 2002). The students enjoyed measuring and combining chemicals in order to achieve the foamy overflow in the large dishpans. They were amazed with the outcome, but were also required to explain the acid/base chemistry behind the experiment. The small, but interesting stations were a nice cap-off to the acid/base section of this unit.

WEEK 6:

The final week of the term came quickly and we started by tie-dying tee shirts. The students were looking forward to this activity from the initial day when I gave an overview of the course to them. They were meticulous about their design and were provided with five different colors to enhance their tee shirts. Along with the tee shirts, the students dyed some multi-fibered ribbon in order to see how a single dye adheres to different substrates and shows different hues.

The following day was devoted to light. I introduced the electromagnetic spectrum of light and used some polarizing light filters on the overhead transparency in order for them to see the blending of additive color. We also placed prisms in the window in order to catch the rays from the sun. Separating individual wavelengths resulting in the colors of a rainbow was discussed through the visible portion of the spectrum passing through a prism. We did an "Emission Spectroscopy Lab" (see Appendix B-13) where the students placed metal ions in fire in order to observe the color changes that were emitted from each metal when it moved from the ground state to an excited state. Phosphorescence, fluorescence and thermoluminescence were demonstrated with the aid of heat sensitive products, light sticks and glow in the dark vinyl sheets.

I had a make-up day where students were able to finish previous work they had not completed. The rule in my class is that they need to be working on assignments for my class during this time and hopefully, hand in late assignments to be graded. I also had a few fun sheets that were related to color chemistry available for any student who was completely caught up. This gave them an opportunity to earn extra credit points on top of their grade. I do not allow the fun sheets in lieu of the regular assignments and rarely have to use this option. They were not allowed to do "nothing," but a few students also opted to help others finish labs from previous days.

I set up a lab practical where students moved from station-to-station around the classroom in order to recall concepts we studied within the term. I had a total of fifteen stations and they ranged from naming minerals to measuring items to describing the chemistry behind the products they were using. Each station had something for the students to manipulate and the questions/directions were written on index cards for them to answer. I used this exercise as a graded review to the post-test that was scheduled for the following day. Students were able to ask questions and get any clarification they needed for the final in the term. The "Post Evaluation--Chemistry of Color" (see Appendix A-8) was given to the students on the final day of the term. This was not the same test the students took for the pre-evaluation test, however they were presented with the same questions using different formats (see Appendix A-3 and A-8). They were not comfortable with a "test" format, but were more receptive to my needs for the research by this point. Assessing the students' work was performed on points being awarded for lab participation and the write up/answer the lab questions for each assignment they did. They were able to work in groups of two when they were present and earn seventy percent of their grades from the work and participation points. The additional thirty percent of the grade related to attendance issues (see Appendix A-1). Lab participation points were awarded for their actual involvement in the lab and the means of evaluating their work was easily accomplished because there were only twelve students to assess. I make a point of reading every word they write in response to essay questions and grade the work on accuracy. I also do not hand back the graded work to prevent cheating, but all students are allowed the opportunity to see the work after I grade it. They are able to assess their work within a week of completion.

RESULTS/EVALUATION

The “Chemistry of Color” students came from a wide variety of backgrounds, but they all shared a common interest in learning about color. As a group, they worked very well together. They shared laboratory results with each other in an effort to better understand the chemistry concepts being studied. Students who took the course did well on individual assignments (see Table 3).

Table 3: Individual Grades for Chemistry of Color Assignments

STUDENT	GEMS	VOCAB	MINERAL	INK USAGE	WRITE LIFE	SATURATION	2.1 ART CHEM	POLAR	SOLUBILITY	SPECTRA	WAVE	PIGMENT	PAINT INK	CHROMATOG	CABBAGE	TITRATION	ACID BASE	EMISSION	PRACTICAL
A	7	12	10	16	20	10	5	5	10	12	4	10	18	10		5	20		15
B	6.5	12																	
C	6			12							5								
D				12							5								
E	7	10		10	15		5			20	5			6			7		
F	8	12	8	20	20	7	5	5	10	18	5	10	15	10			20		5
G	8	12	8	20	20	10	5	4	10	19.5	4	8	20	10	5		20	8	13
H	7	11	6	10	20	8	5	3	8	13	2		18	20	4	4	20		10
I	7.5	11	10	6	15	9		4	2		5	8	20	10	3	4	20	7	12
J	6	10.5	9	12	17	9	5		10	18	5	9	18	10	5	5	18	6	12
K	7	6		4			5			15	5			5			15		
L	7	10.5	8	20	15		5	4		9			12	10	5	5	20		13

Most points were lost due to incomplete work and missing assignments. The teaching methods we employ at Meridian encourage students to ask questions as soon as they seem not to understand the concepts and the hands-on instructional approach lends itself well to analyzing where the students get confused by the task.

Daily classroom attendance factored into success or failures in the labs (see Table 4). Students were aware of the criteria they had to meet and understood that all labs were not reproducible upon their return from an absence. They accepted responsibility for their own actions and required encouragement and praise for small steps in their path to success.

Table 4: Daily Classroom Attendance (/ = unexcused, X = excused, T = tardy)

Student	A	B	C	D	E	F	G	H	I	J	K	L
10/13				/			X	/				/
10/14		/	/	/			X					/
10/15			/				X					
10/16		/	/	/			X					T
10/17				/			X					/
10/20		/							/			
10/21		drop						X	/			
10/22			/	/								
10/23			/	/								
10/24			T									
10/27			/									
10/28			/	/		T	T		/			T
10/29			X	/						X		

Table 4 (cont'd)

	A	B	C	D	E	F	G	H	I	J	K	L
10/30	X			T								
10/31			X	X		X		X				
11/3			/	/		X			/			X
11/4			/	/			/		T			
11/5			/	/						X		/
11/6			/	/				/				/
11/7	/		drop	drop				/				
11/10						X					X	
11/11								X			X	
11/12						X					X	/
11/13											X	X
11/14					/						X	X
11/17					/							X
11/18							X					
11/19												
11/20	/											
11/21								X			X	

The attendance issue was one of the biggest factors affecting success and failure in the lab performances (see Table 5). Students who were not present on a particular day were required to catch up with the other students by working on labs that were left set-up for a few days. They were encouraged to complete written assignments at home or in their free time because the pace of the course kept them busy in the classroom with the lab work.

Table 5: Daily Assignment/Attendance

DATE	ASSIGNMENT	# OF STUDENTS WHO COMPLETED ASSIGNMENT	# OF STUDENTS PRESENT
10-13	Introduction, Rainbow Connection Demo	---	9/15
10-14	Pre-Evaluation Test	12	7/15
10-15	Color of Gems/Color Vocabulary	11	10/15
10-16	Observing Minerals	7	9/15
10-17	Ink Usage Lab	11	7/15
10-20	Introduction to Excel™	---	10/15
10-21	Write to Life Lab	---	9/12
10-22	Write to Life (cont)	8	10/12
10-23	Color in a Saturated Solution Lab	6	9/12
10-24	Pressure Demo/Activity 2.1 Art in Chemistry	9	11/12
10-27	In service Day	---	----
10-28	Bonding/Ionic vs. Covalent & Polar vs. Non-polar solvents	5	8/12
10-29	Solubility Lab	6	8/12
10-30	Pigment Color & Spectra Lab	8	10/12
10-31	Wave Diagram	11	7/12
11-03	Video-Color/Intro to Pigments & Binders	---	7/12
11-04	Developing Pigment Lab	---	9/12
11-05	Developing Pigment Lab (cont)	6	7/12
11-06	Making Paint &Ink Lab	---	7/12
11-07	Making Paint & Ink Lab	---	7/9
11-10	Making Paint & Ink Lab	7	7/9
11-11	Chromatography Lab	9	7/9
11-12	Magic Pitcher/Cabbage Indicator	4	6/9
11-13	Acid/Base Indicators	5	7/9
11-14	Acid/Base Lab	9	6/9
11-17	Tie-Dye Lab	7	7/9
11-18	Light Demo/Emission Spectroscopy	3	8/9
11-19	Make-Up day	---	9/9
11-20	Lab Practical	7	8/9
11-21	Post Evaluation Test	9	7/9

The twelve students who agreed to be a part of this study come from diverse backgrounds and have unique reasons for selecting the "Chemistry of Color" course for a part of their education. Each one has a story to tell about the journey that ultimately led them to Meridian High and "Chemistry of Color" where they were able to discover their own individual education needs in a student – centered environment. Their stories are genuine and they make no excuses for their values, appearance or character. They will be referred to as different letters of the alphabet to assure anonymity.

Student A was the only male student who chose to take the course. He came to Meridian High on November 26, 2001 in his freshman year after spending nine weeks at Haslett High School in the traditional freshman setting. In an interview, Student A said he chose to come to Meridian because he felt pressured to succeed from everyone at the regular high school and that he could not handle the pressure. He believed his entire career path and future success were being jeopardized in his freshman year and he didn't want to be a failure. In his opinion, there was too much emphasis placed on the high achievers who planned on going to college and the rest of the students were led to believe they didn't mean much to the school.

When he transferred to Meridian High, he found a caring environment that accepted him unconditionally. Meridian's emphasis on each individual's success and the absence of the pressure he had felt at Haslett High made it possible for him to integrate his need to succeed in the classroom with the course requirements in our school.

He is currently in his junior year at Meridian and is dual enrolled between Meridian High School and the Capitol Area Career Center where he is studying welding. He was admitted to the "Chemistry of Color" class with 1.5 credits in science. His performance was good where he completed twelve out of fourteen labs on his own (see Table 3). He preferred to work on labs by himself and asked for help when he needed it. His attendance record included two unexcused absences and one school activity day during which he was on a field trip with another class.

Student B came to Meridian High on September 16, 2002 and was approximately six months pregnant with her first child. She lives in Holt/South Lansing and has to provide her own transportation to the school. During the time she was actively involved with the "Chemistry of Color" course, she was juggling a ten-month old daughter, arguing with other parents in the nursery and finding out she was pregnant with her second child.

Her attendance at Meridian has always been somewhat sporadic and she has had terms in which she has missed more days than she has attended. To date, she has attempted to earn 4.25 credits in science and was accepted in the course with 1.5 credits. Her failures are attributable to her attendance record since she certainly has the capabilities to handle the work. In the first week of the class, she missed three days and was verbally fighting with two other teen parents in the class so the decision was made between the parenting teacher, who also is her mentor teacher, and myself to transfer her to the Astronomy class where she would have a better chance at success. The work she completed for the "Chemistry of Color" course was good, but she was affecting others in the room. She is a senior and should graduate this year.

Student C was a freshman who came to Meridian as a pregnant teen. She delivered her baby in September and was allowed three weeks off school to recuperate. Her first day back from maternity leave was slated for the first day of the "Chemistry of Color" class on October 13, 2003. Student C had transportation difficulties due to her family living in Lansing and only made it to the "Chemistry of Color" class four times in the term. When her schedule was chosen with her mentor teacher, she was placed in the class despite not having any credit in science because her older sister was in the class. The thought was that her sister would model appropriate behaviors and would help her to acclimate to the alternative school. Her performance was unsatisfactory because of her attendance and her lack of Introductory Chemistry knowledge. She was very dependent upon others to help her with basic procedures in the lab. She was dropped from our school enrollment on November 7, 2003 due to lack of attendance and has not returned.

Student D came to Meridian on January 27, 2003 as a teen parent who needed the use of the nursery for her son while she finished her high school education. She is our only married student and has been married for two years. Her son was approximately eleven months old when the "Chemistry of Color" course was offered. She found out she was pregnant for her second child and dropped out of school for the term in order to deal with morning sickness, her attendance issues, a demanding job to help ends meet at home and lack of success. She only attended the class three times that term, but has since returned to school with the intent of finishing up and earning her high school diploma this June. When she entered the "Chemistry of Color" class, she had 3.0 credits in science and performed well on the few activities she attempted.

Student E came to Meridian as a day visitor because she had been dropped from Haslett High due to poor attendance in March 2002. She was only allowed one visitation day during which she got a "feel" for our school and decided whether she would like to enroll. Her starting date for Meridian was August 27, 2002 where she entered with 1.0 credit from her freshman year at Haslett High. When I interviewed her about her experiences at the traditional high school, she seemed very hostile and angry. She stated, "They all hated me." When I asked who actually hated her, she responded with the names of the three top administrators, a few teachers and some of the students. In her opinion, they wanted her out of their system at whatever cost.

At Meridian, she was met with academic offerings that challenged her and kept her in school despite the fact that she became pregnant and had an "on again, off again" relationship with a boy in our system. In the year and a half that she has been with us, she has earned 8.75 credits, 1.75 of them being awarded in science.

Her attitude about school is very passive. She is quiet and doesn't value the school nursery program. Her baby doesn't attend our school and she avoids the other teen parents with similar lifestyles. She feels as if she must attend school in order to keep her father's Social Security check coming and her diploma is so far away that she doesn't believe she will ever earn it. Her performance in the course was sporadic. Many days, she sat with the work and didn't attempt to do it. She only attempted and completed five out of fourteen labs and was caught cheating on the pre-evaluation assignment.

Student F came to Meridian on August 27, 2002 at the beginning of her junior year. She transferred from Williamston High School and was pregnant with her first child. Her son was twelve months old at the time of the "Chemistry of Color" course. She uses the on-site nursery while she finishes her high school education. She is a senior who will be graduating in June and had 3.0 credits in science when the class started.

When I interviewed her about her experiences at Meridian, she stated that she originally thought she would attend Meridian High only until she had her baby and planned to return to Williamston to finish her high school education. Once she was comfortable with our school, she decided to complete her education at Meridian High because she was able to link up with other teen moms, use the on-site day care center, learn about services that are pertinent to her needs and enjoy success in her coursework. Her performance in the course was good and strong. She partnered up with Student G and was able to contribute her fair share to the group. She was able to analyze the written component of the work easily. Her attendance during the course included four excused absences documented by notes from her doctor's office.

Student G came to Meridian for her senior year. Her starting date was August 26, 2003. She transferred from Williamston High where she was successful in her academics. She was pregnant and delivered her baby in September. She actually missed the first week of class due to her three-week maternity leave. She was recommended for the "Chemistry of Color" course by her mentor teacher because she needed the challenges that our upper-level classes offer. She had 3.0 credits in science when the course started and was the strongest student in the class. Her background in science helped to make her a class leader who could help others problem-solve lab expectations and written analysis questions.

She acclimated to Meridian and has made a nice transition to the alternative school. In her interview, she stated that she originally wanted to graduate with her class from Williamston, but opted to finish at Meridian because of the nursery option and the new friends she made who had similar needs. Her attendance included six excused absences and one unexcused absence. She will be graduating in June.

Student H attended Meridian High for her junior and senior years. She started attending on November 18, 2002 with some medical and emotional difficulties. After leaving Okemos High, she was placed in rehab/treatment for anorexia nervosa. Upon returning home from a long-term residential treatment program, she was recommended to Meridian to complete her high school education. She became actively involved in our TATU (Teens Against Tobacco Use) program and was also involved on our Prom committee. She acclimated well in the school and was named Rotary Student of the Month in February of 2004. By the time she took the "Chemistry of Color" course, she had 2.25 science credits and performed at a satisfactory level. She didn't care to partner up with other students and worked at her own pace on the labs for the course. Her attendance record included five absences and two school field trip activities that kept her out of class for a total of seven days.

Student I recently moved to the Haslett area from Alpena, MI. She started attending Meridian on August 26, 2003 and quickly felt a comfort level in my classroom and with me. She is in my mentor group and chooses to take my classes every term.

When the "Chemistry of Color" course was offered, she had earned .25 credits, but had attempted 2.75 credits in science. Her performance was good. She worked hard to keep up with the pace of the course and would stop in on her lunch hour for additional help to comprehend the work. She had experienced an attendance issue in the traditional high school in Alpena and was slated for their Adult Ed program, but was waiting to turn sixteen. Her mother did some research about the schools in this geographic area and felt as if Meridian High was the best fit for her daughter's needs. Student I's attendance improved as she only had four unexcused absences for the term.

Student J started school at Meridian High on December 11, 2001 as a freshman. She was pregnant and had not attended school since she finished up at Holt Jr. High in June of 2001. Upon the recommendation of her cousin, her family looked to Meridian as an alternative source for her high school education. She travels from Holt daily in order to attend school and needs the on-site nursery to care for her son as she progresses toward graduation.

She is currently dual enrolled between Meridian High and the Capitol Area Career Center in the Health Occupations program. She has had all of her science education in my classroom and entered the “Chemistry of Color” course with 1.5 credits in science. She is a hard worker who wants to do well in school and was able to keep up with the demands of the course. She was very interested in the labs and was able to integrate the concepts from the labs back to the written work. Her attendance has always been great. During the course, she had one excused absence and one field trip day.

Student K enrolled at Meridian High on August 26, 2003 and is classified as a senior. She has been home-schooled for her entire high school career and previously attended Lansing Community College as an Art student. She did not have any traditional high school credits prior to enrolling at Meridian, but needed to earn her general education diploma (GED) in order to qualify for acceptance at the university level. Her home-schooled education focused on the Social Sciences and English. She attends Meridian only in the mornings and works a full time job in one of the cafeterias at MSU, starting at 11:30 A.M. every day. Her focus at Meridian is to concentrate her efforts on math and science as she sees these as her weak areas. She does not have the discipline to stay on task if she is not interested in the work. She spends a lot of class time drawing pictures and asking if she can perform her own “sidebar” experiments. My original perception was that she would be one of my strong students because of the esthetic appeal of color and the tie-in with an art theme, but quickly found out that she was not interested in the scientific aspect of the work. She is limited to which classes are available to her and has gotten comfortable with the two teachers she has had. Her attendance included missing an entire week of school for a family vacation to Malta.

<u>Student L</u> came to Meridian High on October 7, 2002. She was unsuccessful in her education at Haslett High School as she had earned only 4.0 credits in her freshman year. Her academics were suffering and her attendance record showed that she wasn't returning to the traditional high school after lunch every day. She has a substance abuse problem and had been placed in a long-term rehabilitation boarding school facility in Utah for part of her education. Upon returning to Haslett, she reentered our school and continued to earn credits. She is currently classified as a junior with a total of 12.0 credits. Her science education includes attempting 5.75 credits, but only earning 2.25 successful credits. Her capabilities are strong, but her personal choices interfere with her success at school. Her performance in the class was weak because of her attendance. She missed quite a bit of school and feels entitled to days off. She maximized her absences early in the term and couldn't afford to miss any more when she had to have her wisdom teeth removed. This compounded the attendance issue with a total of ten absences. This equates to one third of the course where she wasn't present.

Comparison of Pre-test to Post-test

The "Chemistry of Color" Pre-Evaluation elicited a wide range of responses for me to assess regarding my students' prior understanding of the vocabulary and the concepts to be covered in the course. The students did not do very well on the pre-assessment and opted to answer only the questions with which they were comfortable, demonstrating some prior knowledge (see Figure 6 and Figure 7). By not attempting to answer all questions on the test form, they limited themselves on their ability to score well. When I questioned them individually, responses ranged from "I don't know any of this stuff" to "Aren't you supposed to teach us about this first?"

The questions they attempted to answer were compared to the questions they answered correctly and a correlation between the two was evident (see Figure 8 and Figure 9). For the most part, if they knew something about the question or vocabulary, they expressed themselves and if they did not, they left the questions blank. For example, when comparing the two sets of data in the graphs, Student A attempted to answer four out of eight questions and succeeded in correctly answering three out of eight questions (see Figure 6 and Figure 8). This pattern of answering only a few questions was the norm for the entire group of students. They fared better with the questions and chose to give less attention to the definitions on the vocabulary. The comparison of attempted vocabulary and correct responses to vocabulary showed a few students attempting to answer, yet not having a grasp of the concepts (see Figure 7 and Figure 9). For example, Student A attempted nine out of ten vocabulary terms, but was unsuccessful in every attempt. Five students didn't even make the attempt at the vocabulary so the pattern went in two directions (see Figure 7 and Figure 9). They either made an attempt without success or they did not attempt the work.

Figure 6: Pre-Evaluation Atempted Essay Questions

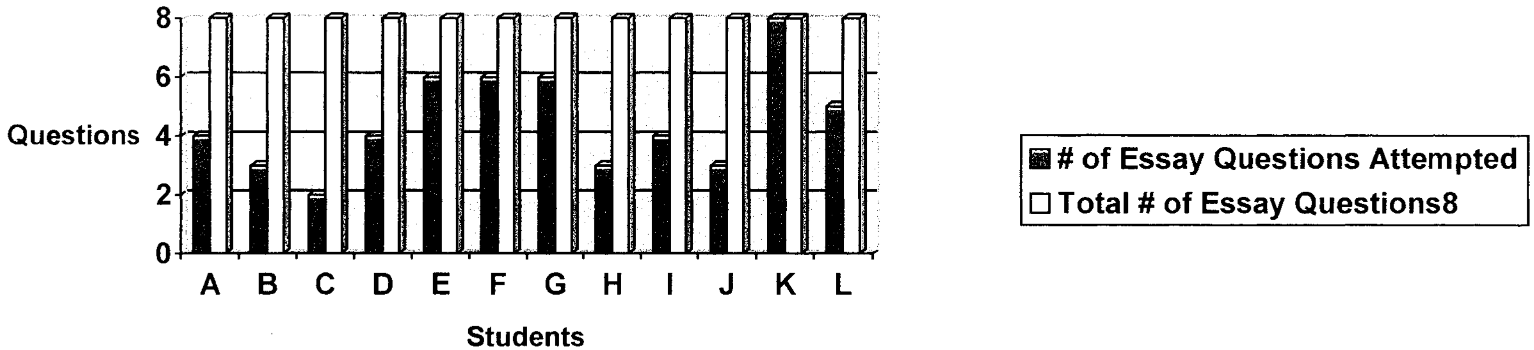


Figure 7: Pre-Evaluation Atempted Vocabulary

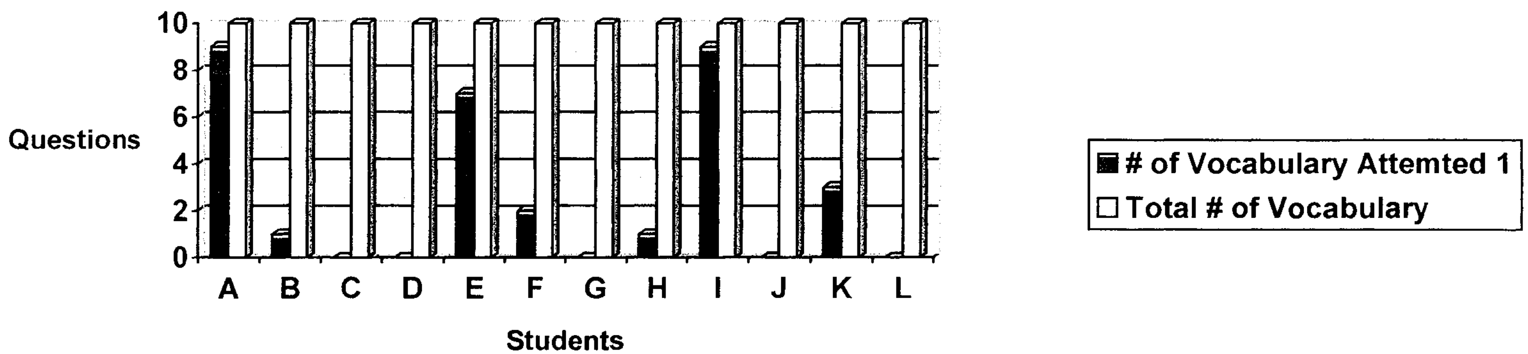


Figure 8: Chemistry of Color Correct Responses to Pre-Evaluation Essay Questions

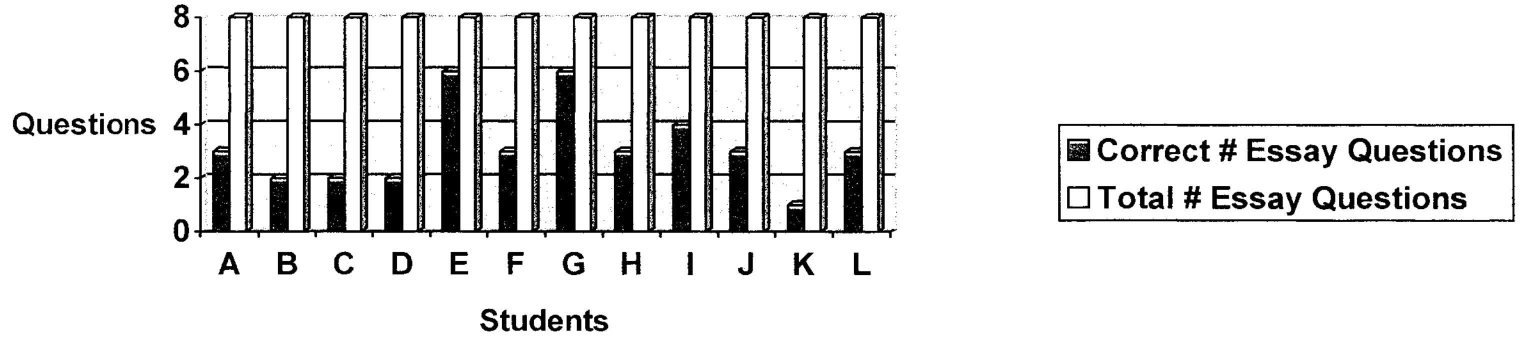
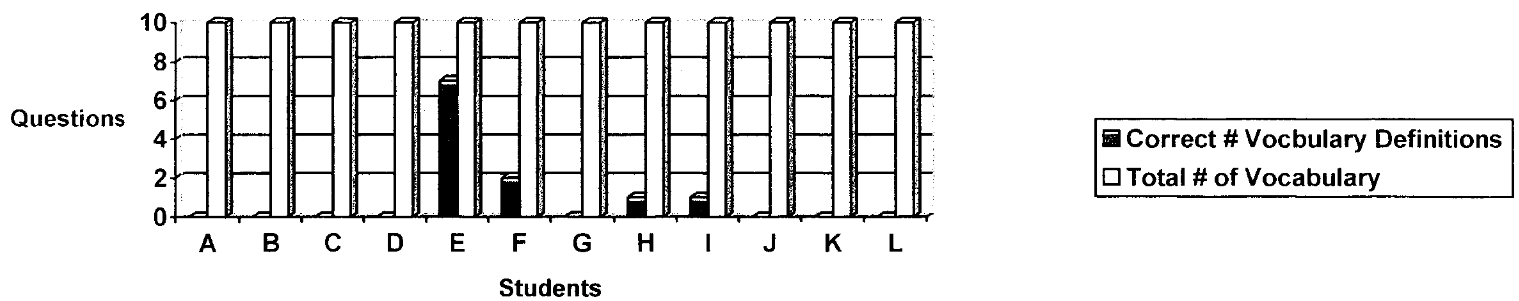


Figure 9: Chemistry of Color Correct Responses to Pre-Evaluation Vocabulary



Examining the student responses to the questions, I found that they basically knew about the same things. Some had knowledge about polar and non-polar solvents without knowing the scientific terms, decimal places in metrics, massing objects, mixing colors and a few even knew a little about acids and bases. The lack of knowledge about the concepts for the upcoming term was evident when the scientific terminology was presented in the vocabulary. They were able to rationalize concepts from the essay questions that were presented in every day terms, but their vocabulary left no doubt they needed assistance in learning new concepts and integrating new words. By comparing each individual question and vocabulary word, I was able to focus my curriculum on the areas that would become new concepts instead of reviewing concepts that were already understood by the majority of the students (see Table 6).

Table 6: Students' Correct Responses to Individual Questions on the Pre-Evaluation

Questions	A	B	C	D	E	F	G	H	I	J	K	L
1	X	X	X	X	X		X	X	X	X		X
2	X				X		X	X	X	X		X
3					X	X	X	X	X			
4							X					
5	X	X	X	X	X	X	X		X	X	X	X
6					X	X	X					
7					X							
8												

Table 6: (cont'd)

Vocabulary	A	B	C	D	E	F	G	H	I	J	K	L
1					X							
2					X							
3					X			X				
4												
5					X	X			X			
6					X							
7					X							
8												
9												
10					X	X						

The course started and the students began to integrate new ideas, concepts and terms as they worked to successfully complete the class. They had a total of fourteen labs they were expected to perform along with various paper and pencil activities to reinforce the concept of chemistry and color. I graded each individual assignment based on a point value system. They earned one point for every question they answered correctly. When students were absent for a lab, they frequently talked with each other about the labs they missed and ask questions to get the general sense of what took place. By doing so, they were able to answer pre-lab questions and post-lab questions that do not pertain to their results in the lab and still earn some credit. They also earned lab participation points based on the difficulty of the lab. They could earn a maximum of ten points per lab in addition to the written assignment part of the grade and I awarded points based on their involvement in the lab. Some students do very well on graded assignments, but do not show much enthusiasm or initiative on the lab work so their grades reflect that. Others are just the opposite. They prefer the lab experiences to explanations and synthesizing the concepts. In the end, the course had a total of 225 possible points to include evaluation of the lab participation, written work from the labs and worksheets. Many students did well in earning the points (see Table 7).

Table 7: Students' Overall Points For the "Chemistry of Color" Course

Student	A	B	C	D	E	F	G	H	I	J	K	L
Points	189	18	23	17	85	178	204	169	153	184	62	143.5

I also factor in their attendance record as it can become an impediment to their overall success at Meridian. My attendance policy (see Appendix A-1) rewards students who get up and come to school regularly. Others are under utilizing their educational opportunities which adversely affects their final grade in the class. From my perspective, even if there is not a graded assignment or lab taking place on a particular day, there is still the opportunity to learn something new in my classroom so the students are expected to be present to earn points. I do allow opportunities for make-up time and work through our after school "Coffee House" once a week or "Saturday School" once per term, where the students can make up some time missed from the classroom.

The post-evaluation for the "Chemistry of Color" (see Appendix A-8) format was set up as a matching, multiple choice and essay test and was not the same evaluation that was used for the pre-evaluation test (see Appendix A-3). The students were presented with the same vocabulary terms in a matching format and the essay questions from the original pre-assessment were presented either in multiple choice or essay format. Their performance on the post-evaluation test resulted in 89% of the students passing the test with a minimum score of 61% (see Table 8).

Table 8: Post-test Final Scores

Student	A	B	C	D	E	F	G	H	I	J	K	L
Score	72%	W	W	W	61%	61%	94%	78%	67%	67%	28%	78%

When the comparison of the pre-test to the post-test was made, I found that the students' attempted to answer all of the questions and vocabulary on the post-test. Once they were presented with the information through the course, they were able to synthesize the concepts (Figure 10 and Figure 11).

Figure 10: Chemistry of Color Post-Evaluation Essay Questions

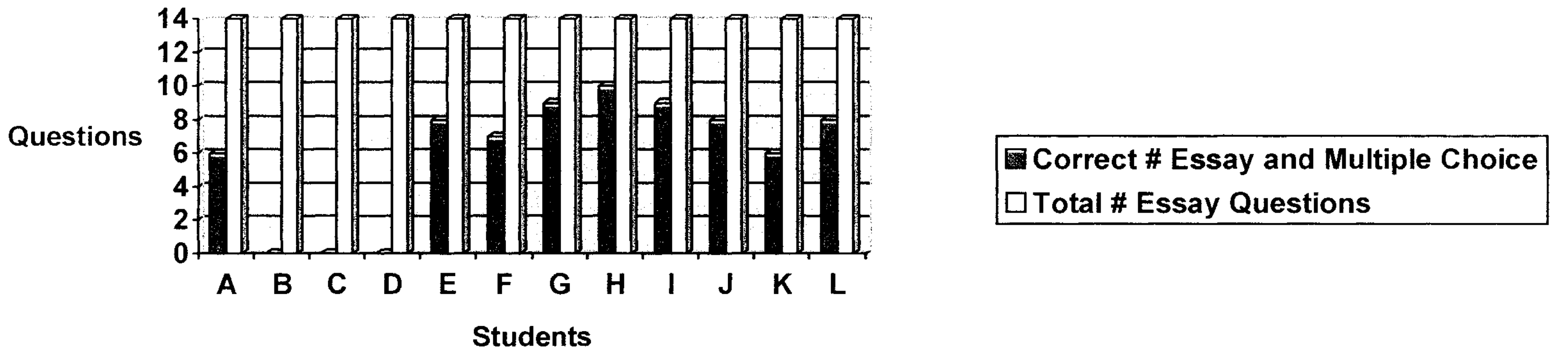
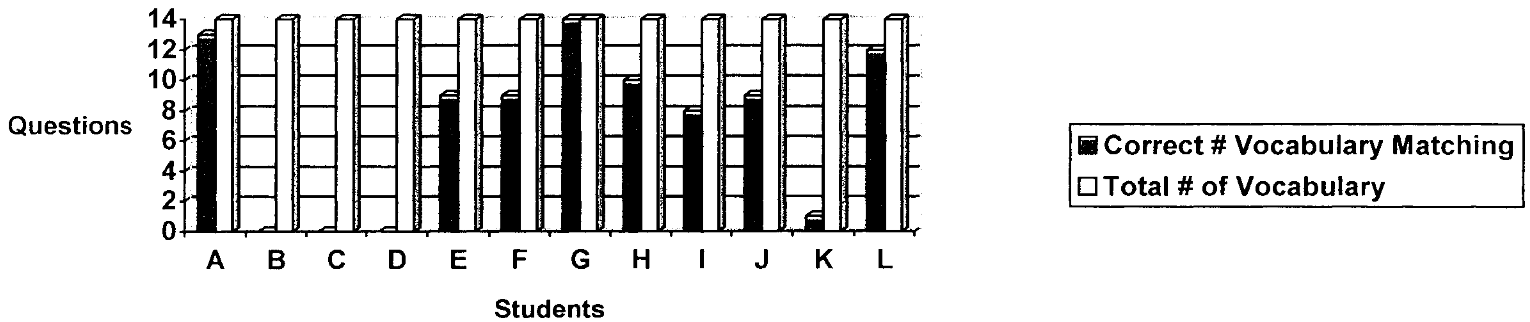


Figure 11: Chemistry of Color Post-Evaluation Vocabulary



The post-evaluation had additional vocabulary words interspersed from the term in order to challenge the students. They were also presented with a few more questions from the term and responded to the test conveying their understanding of the concepts. Comparing “apples to apples”, they also increased their knowledge on the initial vocabulary words (see Table 9). This is a chart comparing the correct answers to the ten vocabulary words they were initially presented from the pre-test when compared to the post-test.

Table 9: Student Pre and Post Test Comparison of 10 Vocabulary Terms.

Student	A	B	C	D	E	F	G	H	I	J	K	L
Pre-test	0	0	0	0	7	2	0	1	1	0	0	0
Post-test	9	W	W	W	5	5	10	7	6	6	1	8

Additionally, the comparison of the pre-test essay question responses to the answers from the post-test for the same questions also produced results that showed an increase in their knowledge (see Table 10). Comparing “apples to apples” once again resulted in an increase in scores for the post-test for every student.

Table 10: Student Pre and Post Test Comparison of 8 Essay Questions.

Student	A	B	C	D	E	F	G	H	I	J	K	L
Pre-test	3	2	2	2	6	3	6	3	4	3	1	3
Post-test	4	W	W	W	6	6	7	7	6	6	4	6

The students’ post-test responses to each individual question were compared to the pre-test responses from Table 6 and a correlation between the information they did not have when the course started and the new information they generated was found (see Table 11).

Table 11: Students' Correct Responses to Individual Questions on the Pre-Evaluation (X) When Compared to Post-Evaluation (+)

Questions	A	B	C	D	E	F	G	H	I	J	K	L
1	X +	X	X	X	X +	+	X +	X +	X +	X +	+	X +
2	X +				X +	+	X +	X +	X +	X +	+	X +
3	+				X +	X +	X +	X +	X +	+		+
4							X +	+				
5	X +	X	X	X	X +	X +	X +	+	X +	X +	X +	X +
6					X +	X +	X +	+	+		+	+
7					X +		+		+	+		
8						+		+		+		+
Vocabulary												
1	+				X +	+	+			+		+
2	+				X +		+	+	+	+	+	+
3	+				X +		+	X +		+		
4	+					+	+	+	+			+
5	+				X	X +	+		X +			+
6					X +		+	+		+		+
7	+				X		+	+	+	+		+
8	+				+	+	+	+		+		
9	+						+	+	+			+
10	+				X	X +	+		+			+

They all retained the information they had prior to starting the course and also were able to add to their vocabulary as well as their knowledge of "Chemistry of Color". I was able to assess each individual's learning style and know the students' strengths and weaknesses.

Student A finished the course missing the lab practical day so he had to take the final and the practical on the last day of the term giving up his lunch hour to help his grade. What a difference for the guy who came to Meridian because he was lead to feel like he was a failure at the traditional high school. He finished the course with a B+.

Students B, C and D all dropped for the term, but Students B and D returned to finish up their senior years. They both delivered their second children before the school year ended and managed to continue earning credits so they could succeed.

Student E was caught cheating on the pre-evaluation and only attempted nine assignments out of nineteen. She was very passive about lab participation and refused to do most assignments. Her involvement in school dropped off dramatically after the course and she only attends school sporadically. She has not earned any credit since the "Chemistry of Color". She did not pass the term.

Student F was very conscience about her work performance in class and on her lab work. She completed most assignments and tailed off toward the end due to her son's illness that caused her to miss a few days of school. She finished the term with a B.

Student G really enjoyed the challenges of the class. She was absent for the first week of the course on maternity leave, but was able to catch up without any problem. Her academics were very important and she really enjoyed the labs. Her final grade for the course was an A.

Student H was a pleasure to have in the class. She spent time outside of class with the school social worker on numerous occasions and would rush through some labs because of it. Her work paid off as she earned a C+ in the end.

Student I was very interested in the course, but lacked in a science-based background so she struggled with concepts. She enjoyed the hands-on experiences and required additional help on many labs. Her final grade was a C.

Student J was very cooperative. She was goal oriented and also had to leave twenty minutes early every day to catch a bus for the career center. It didn't hurt her lab performance because she would take the write-ups with her and work on them on her own time. She finished the course with a B+.

Student K beats to her own drum. She is a GED student who isn't driven by grades. Her participation was very sporadic and she did not pass the course.

Student L had an attendance issue that hurt her. She was unable to make up the missing work and struggled to earn a D-.

Finally, the course was over and the students had learned about color. I omitted the pre-test and the post-test from their final grades for the course because I did not want my research assignment for MSU to affect their grades. 78% of the students who stayed with the class earned full credit for the course.

DISCUSSION

Once the students completed the "Chemistry of Color" course, they were better prepared in their knowledge about career opportunities that needed employees with science-based backgrounds to work with pigments and color. The information presented in the course also showcased opportunities for chemistry majors that involve the use of chemicals without the ultimate use being explosives, firearms and toxicity. They understood what it would take to continue their study of color chemistry at the college level through a science-based education.

The data from both the pre-test and the post-test indicates that the students learned new concepts that were presented through the course. They were receptive to new ideas and began to integrate the "Chemistry of Color" concepts that tied into an "Art in Science" theme because they had experienced a chemistry course with practical uses. By organizing labs around central themes that included hands-on, every-day science, the students performed labs based on topics of their interest. Research has shown that presenting science objectively and precisely in an artistic and imaginative format leads students to a more complete understanding of science. Although the standard Chemistry curriculum does a minimal job of covering color, Michael Freemantle (2001), states, "Color is the most visual, pervasive example of the importance of chemistry to our lives". Along with many other factors, this concept helped to motivate me to develop the course on color.

The individual labs that the students performed worked well in meeting the objectives of the term. The students needed activities that reinforced the topics that were presented in small, sequential steps. The success they felt by performing the labs through hands-on experiences, motivated them to learn. I witnessed many students who didn't understand what the task of the day was meant to teach, come full circle after the lab and explain to others in the class the science behind the lab. For example, the demonstration on high-altitude pressure differences in ink pens with a liquid reservoir and an air pocket loaned itself nicely to discussing Boyle's Law. The students hadn't given much thought to the manufacturing of pens needing to deal with pressure chambers and pressure increases causing the gas in the reservoir to decrease being related to volume increases in equal proportions. They had learned about pressure and volume and did some calculations in their physical science classes, but never related the concept to every day uses like liquid reservoir pens until they witnessed the class demonstration. They were able to manipulate other pens with similar conditions that aided in their information processing. Once they understood the concept, they visualized outcomes from story problems about pressure and volume without the link to color because they developed a greater understanding through their active involvement in their learning. This increased their likelihood of remembering the pressure and volume concepts, retaining the information and helped with the ability to transfer the concepts to other pressure and volume situations.

Other labs were excellent in presenting information in an esthetic way. The students enjoyed the "Developing Pigment Lab"(see Appendix B-9) that emphasized single placement reactions, double placement reactions and synthesis reactions. The mixing of various chemicals to produce new colors occurs frequently in acid/base chemistry with indicators, but the ability to produce viable products as an outcome of the lab made this experience unique and it sparked their interest. They were anxious to start the next lab, "Making Ink and Paint as a Surface Coating Lab" (see Appendix B-10). They knew they were building on their newly acquired knowledge about chemical reactions in order to develop the inks and paints from the pigments and they would be able to present their science learning artistically and imaginatively as well as objectively and precisely. By developing the surface coatings, they had a more complete understanding of substrates, solvents, binders and capillary action. This enhanced their knowledge of the science being studied because of the labs they performed (see Appendices B-6, B-7, B-8, B-9 and B-10).

Unfortunately, all assignments weren't good learning experiences for the students. The pre-test was the hardest assignment the students' had to deal with. Their attempts to answer the individual questions were made only after I explained the purpose for a second time. When the pre-test was handed out, they were not happy with answering questions about topics they felt they signed up for the class to learn about. The feeling in the room was as if I was setting them up for a failure. When they got to the vocabulary terms, they didn't take the assignment seriously and handed it in with most responses unanswered.

Looking back, I think they tried to give me what I was looking for until they felt overwhelmed. There wasn't much that could be done to convince them that they came to the classroom with previous knowledge and that their knowledge needed to be assessed on what they actually knew verses making assumptions about their prior knowledge. In the future, any pre-test that assesses prior knowledge would have a different format. Expecting the students to write definitions without a pool of possible choices should be modified. They might have done better had it been presented in a matching type format and I will try this approach next year. At the time of development, I did not want the pre-test to look like a typical test because of the "test anxiety" issues we deal with at Meridian so the decision was made to do essay type questions and straight definitions and it didn't work as well as expected.

A few of the labs need some slight modifications. For the most part, the labs were successful in allowing hands-on interactions and the outcomes were what was expected, but the students' explanations to the post-lab questions and the calculations made me feel as if they needed more practice with problems that were similar to the experiment. I had to walk the students through some of the calculations because they understood the process when performing the lab, but struggled with the math aspect.

Another obstacle I faced was the students' lack of regular attendance. This put many students behind on the labs and it was dealt with by keeping labs set up for a few days and allowing students to work at their own pace in order to catch up on the work. This only works for the students who show up regularly and miss a day here and there. The ones who show up sporadically fall further and further behind their classmates, need more individualized attention and generally have more issues in comprehension. They also are forced to forsake some of the work and complete what they can in order to keep up with the pace of the course. The art teacher was very interested in the new chemistry course and offered suggestions on ways for us to integrate our curricula to accommodate the students with an artistic flair. She liked me teaching the students how to incorporate a variety of scientific techniques in the development of paints, pigments and glazes. She would like to have her students use the products that are developed in the chemistry lab to accentuate their own creative artwork. According to Denio (2001), “The potter with a chemistry background is at a great advantage in achieving the perfect glaze.” The students should enjoy the cross-curriculum mesh between the chemistry department and the art department. Currently, the art teacher purchases her paint and glaze supplies from industry and would welcome new sources to enhance her curriculum. For example, different media, including three-dimensional works of art, like clay, should be enhanced with the aid of the chemistry curriculum and the development of the glazes they need in the firing process. The art teacher also has a background in art history and would become involved in teaching the history of developing products from organic and inorganic sources to use in the development of color. We have been talking about different ways of team teaching both of our classes in order to integrate a variety of artistic concepts in the chemistry curriculum, but need to have more concrete lesson plans that we will work on over the summer of 2004.

I applied for and received an Innovation Grant from the National Education Association (NEA) Foundation in February of 2004 in order to teach the "Chemistry of Color" course. The grant money became available to me after the pilot course had been taught and it is greatly appreciated. The science department can always use more supplies as the chemistry classroom was built six years ago and was supplied with a minimum of glassware, balances, and chemicals. The science budget for the start-up of chemistry had to service all of the different science curricula offered in our building. Obtaining needed supplies is always a challenge and many labs are unable to be implemented because of a lack of funding or else I have to borrow equipment from the traditional high school in order to challenge the students who need hands-on interactive lessons to keep their interest. The only other source of funding for the "Chemistry of Color" course was a limited science department budget that is shared by the two science teachers. Budget cuts have targeted supplies in the past few years and more cuts are expected in the future so the grant came at a great time.

The $5000 grant proposal was written in the fall of 2003 as the planning of the pilot course was underway. I had to look to the future and decide which supplies I would need in order to help teach the "Chemistry of Color" course (see Appendix A-9).

In the future, an emphasis on the physics of light will be a goal because the course is weak in the area of integrating a small amount of basic physics. In the pilot course, only one day was devoted to the physics of light and color. Using spectrum tubes to see electrons emit different colors of light is a great crossover from chemistry to physics. The contrast between subtractive light and additive color can be demonstrated with the use of a light box and an overhead projector with polarizing light filters. The students were very attentive to the various demonstrations that were performed with light and color and offered their interpretations to the science behind the visuals. Building shoebox spectroscopes, developing film and understanding anamorphic art are a few ideas that need to be developed in the future to incorporate the art in science theme with physics.

Another area that needs a bit more attention is in the history and development of natural dyes from minerals. The mineral lab that I developed could use more mineral specimens so the students can work at individual stations within smaller groups without having to share the few specimens I have for them to manipulate. With more samples, the streak, luster and hardness tests can be individually performed and students wouldn't rely on each other for data as much as they did in the pilot course.

The chemistry that was taught in the course was strong. The students worked well with the chemicals and enjoyed the hands-on interactions. Integrating measurement techniques, metrics, saturation points, bonding, solubility, reactions, chromatography and acid/base chemistry was all done with some detail throughout the course. Development of pigments, paints and ink for use by the art class would require more time in the lab with a emphasis on manufacturing a product for a customer. I have purchased a few more resource books on dyes, paints and color since the course ended and will try to integrate more ideas as I continue to teach the course.

One of the nicest aspects of working with the alternative students at Meridian High is that meeting their needs requires the teachers to be unique and creative in the lesson plan design. The school administration totally supports new ideas and innovations that encourage the students to think "outside the box", yet acquire the information needed to successfully complete the courses. The "Chemistry of Color" offering was just the type of course that encouraged students to retain concepts by taking risks in their divergent thinking. A healthy level of creativity helps to capture the students' imagination that leads to them returning their best work.

My experience from teaching "Chemistry of Color" can be applied to some of the other courses I teach. The hands-on labs that aid in synthesizing information appeals to the students and works in all of the science curricula. They need the guidance and direction to pursue new ideas and concepts. Applying assessments in a pre-test/post-test format could be beneficial as it would allow me to develop my curriculum around concepts the students do not know. The dynamics of the class will dictate what direction I need to go.

APPENDICES A-1 → A-9

Appendix A-1

CHEMISTRY of COLOR SYLLABUS
October 13, 2003—November 21, 2003

***COURSE OBJECTIVE*:** This course is designed for students to learn about the physical and chemical characteristics of color as it relates to the manufacturing of pens, markers and paints. Acid/base chemistry, solubility, saturation and types of reactions will be covered. This course is lab-based and requires class attendance to complete successfully.

***GRADING SYSTEM*:** Grades will be broken down into 20-10-70 percentages.

1. **Attendance: --You Must Be Here! 20%**
   - You are expected to be in school a minimum of 80% of the time. (Excused or Unexcused). Once you miss three days, your grade will drop as follows:
     4=90%
     5=80%
     6=70%
     7=60%
     8 or more absences, you will lose 20% of your grade.

(Note: More than six unexcused absences results in a failing grade as per school policy).

2. **Tardies: --You need to be on time to class! 10%**
   - You are expected to be here on time. The accumulation of tardies will affect your final grade. Once you are late more than four times, your grade will drop as outlined above.

(Note: Three tardies equals an unexcused absence per school policy).

Figure 5: Syllabus (cont'd)

3. **Effort: --You need to accomplish the work and class expectations every day during class. 70%**
   - Labs and hands-on activities must be completed in a timely manner on the day assigned. They are difficult to make up and you cannot substitute alternative bookwork assignments to replace them.
   - Worksheets, drawings and other assessment activities are to be completed in a reasonable amount of time.
   - Quality of work will be assessed to prove your understanding of work.

Appendix A-2

The Rainbow Connection

Pre-demo Knowledge:

Students are at the beginning of a unit on Art in Science and will not have information on acid/base chemistry from classroom discussion. They will be viewing the demo with the intent of questioning them afterwards with how it was done. The demonstration has three indicators that are completely colorless in acidic solutions, but form the primary colors in basic solution.

Materials Needed: *Reagents:*

The following combinations of indicators give the rainbow of color needed. Each of the following indicator combinations is dissolved in 30 ml of 95% ethanol and stored in 30 ml dropping bottles labeled with the color indicated.

RED	1.5 g phenolphthalein plus 3.0 g *m* nitrophenol
ORANGE	0.45 g phenolphthalein plus 6.0 g *m* nitrophenol
YELLOW	6.0 g *m* nitrophenol
GREEN	0.6 g thymophthalein plus 6.0 g *m* nitrophenol
BLUE	1.5 g thymophthalein
VIOLET	0.9 g phenolphthalein plus 0.4 g thymophthalein

Acid-Alcohol Solution—Mix 250 ml of 0.05 M aqueous H_2SO_4 with 250 ml of 95% ethanol. Transfer the liquid to a bottle equipped with an automatic shot dispenser that delivers 1.5 oz per shot.

NaOH Solution #1—Transfer 1200 ml of a 0.12 M NaOH solution to a clear glass pitcher.

NaOH Solution #2—Prepare a dropper bottle containing 100 ml of a 0.2 M aqueous NaOH soluton.

H_2SO_4 Glycerin Solution—Dissolve 10 ml of 18 M H_2SO_4 in 20 ml of glycerol and transfer the solution into a dropper bottle.

Procedure:

Clean six glass beakers and arrange in a single row on a demonstration table. Place two drops of red indicator in the first beaker making sure not to allow any to splash on the sides. Add two drops of orange indicator to the second beaker and continue adding two drops of each indicator in order to form a rainbow sequence of red to violet. This should be done at least one hour ahead of time where the students are not allowed to see the indicator evaporate. The film of indicator should not be noticeable by the audience.

Pick up each beaker in succession and wipe the sides clean with a towel and then place them back in their position on the table. Do NOT wipe the indicator off the bottoms of the beakers.

Appendix A-2 (cont'd)

Equal volumes, 1.5 oz from the shot dispenser, of the acid/alcohol solution are poured from the bottle into each beaker. Try to direct the liquid stream away from the indicator film on the bottom. The less the indicator disperses into the solution, the better the effect in the next operation.

Use the pitcher of .012 M NaOH solution to fill the beaker to the halfway point. Pour the liquid slowly, directing the liquid toward the sides. If the base comes in contact with the indicator, a momentary flash of color may be observed and this should be avoided. Look at the six beakers that are half filled with what appears to be a water-clear solution. Look at the pitcher and notice that there is enough liquid to add more to the beakers and proceed to do so. Start with the first beaker and pour rapidly until the beaker is filled to approximately ¾ inches from the top. The liquids should change instantly to one of the rainbow colors. The rapid addition of base to the acidic solution should result in an instantaneous formation of the base form of the indicator in each solution.

Add enough of the H_2SO_4-glycerine solution to each beaker to return them to their original acidic conditions. The same amount should be added drop-wise to the center of each beaker. Three drops should be adequate. When the last beaker is filled, squirt about two droppers full of the acid-glycerin solution into the pitcher in an inobtrusive way so as not to let the audience see this step. If carried out correctly, the very dense acid-glycerin solution will sink to the bottom of the beaker without dissolving and the indicator should remain in its basic form with color in the beakers. To insure this, a very viscous acid-glycerin solution should be used.

Each solution in the beakers should be stirred rapidly to cause the color to disappear. You must not wait too long before stirring to mix the solutions or else the colors begin to fade prematurely.

Using the dropper bottle containing the 0.2 M NaOH solution and a stirring rod, rapidly titrate the contents of each beaker back to its original color.

The beakers of solution are then poured, one at a time, back into the pitcher. The result is a colorless solution much like the original.

References:

Hutton, Bill. Iowa State University. J. of Chem Ed., February, 1984.

Knoespel, Sheldon. Michigan State University. Chemical Demonstrator.

Appendix A-3

Chemistry of Color Pre-Evaluation Knowledge

Answer the following questions to the best of your ability.

1. What is the difference between permanent and washable markers?

2. How many decimal places are there in a thousandth of a gram?

3. How much does a mole of water weigh?

4. How is caffeine extracted from the colas and tea to produce caffeine-free products?

5. What colors make up brown?

6. What is the difference between acids and bases?

Appendix A-3 (cont'd)

7. What is the purpose of chromatography?

8. What three things are needed to formulate paint or ink?

Define the following terms

1. Titration

2. Immiscible

3. Saturation point

4. Polar solvent

Appendix A-3 (cont'd)

5. pH

6. Intensity

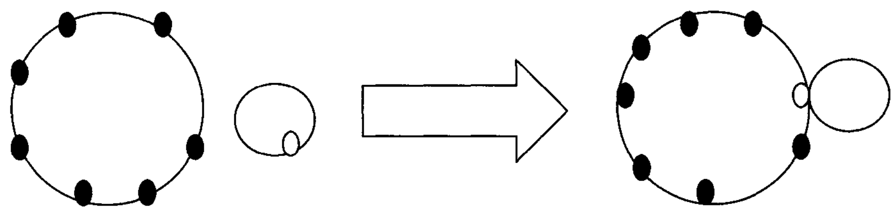
7. Supersaturated

8. Non-polar covalent bond

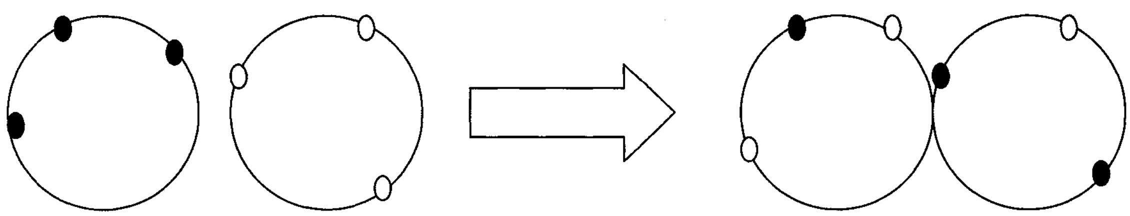
9. Capillary action

10. Solute

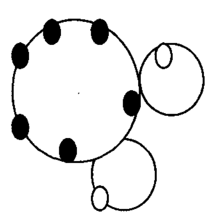
Appendix A-4: Ionic Bonding *(Electrons are given up to other atoms)*



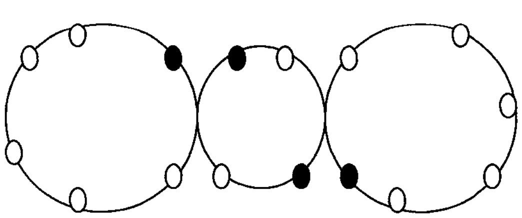
Appendix A-5: Covalent Bonding *(Electrons are shared between atoms)*



Appendix A-6: Polar Covalent Bonds *(unequal distribution of charge)*



Appendix A-7: Non-Polar Covalent Bonds *(equal distribution of charge)*



Appendix A-8

Post-Evaluation: Chemistry of Color

Matching: On the blank spaces, write the letter of the definition that defines the vocabulary term.

1.________Immiscible	A. increase the H^+ concentration in aqueous solution, taste sour
2.________Titration	B. does not mix
3.________Polar	C. dissolving medium
4.________Chromatography	D. saturation of color
5.________Intensity	E. uneven distribution of charge
6.________Supersaturated	F. supplies color
7.________Acid	G. hardener that forms a continuous film on surface
8.________Covalent bond	H. controlled addition and measurement of solution
9.________Pigment	I. Increase the OH^- concentration in aqueous solution
10.________Solvent	J. separation of color
11.________Non-polar	K. excessive amount of solute does not come out of solution
12.________Base	L. even distribution of charge
13.________Permanent	M. sharing electron pairs between atoms
14.________Binder	N. does not dissolve in water

Multiple Choice: On the blank line, write the letter preceding the word or expression that best completes or answers the question.

1. ________What three substances are needed to make paint?
   a) dye, thickener and pigment
   b) pigment, solute and preservative
   c) pigment, binder and solvent
   d) binder, solvent and fungicide

2. ________How many decimal places are in a thousandth of a gram?
   a) 2 b) 10
   c) 3 d) 1000

Appendix A-8 (cont'd)

3. ________Which of the following are not Sanford products?
   a) Sharpie b) Crayola
   c) Papermate d) Colorific

4. ________What is the mass of a mole of water?
   a) 18 g b) 16 ml
   c) 15 mg d) 33 g

5. ________Polar solvents are able to
   a) clean up an oil spill
   b) dissolve permanent inks
   c) wash the dishes
   d) have an equal attraction for the shared electrons

6. ________An acid has all of the following characteristics except
   a) they change colors with indicators
   b) they taste bitter
   c) react with metals to release hydrogen gas
   d) react with bases to produce salts and water
   e) they conduct electrical currents

7. ________Phenolphthalein is used to detect
   a) the presence of an acid
   b) the presence of a base
   c) the presence of water
   d) the presence of protons

8. ________The average life expectancy of a Papermate ™ Pen is
   a) 757 meters b) 456 meters
   c) 611 meters d) 671 meters

9. ________Static cling is caused from
   a) non-polar covalent bonding
   b) electrons having an even distribution of charge
   c) ionic bonding in the dryer
   d) polar covalent bonding

10. ________Caffeine free product are produced by
   a) exposing the leaves or beans to liquid carbon dioxide
   b) soaking the leaves or beans in methylene bromide (CH_2Br_2)
   c) boiling the beans or leaves in water
   d) freeze-drying the coffee, tea or cola

Appendix A-8 (cont'd)

Short Answer: Respond to the following questions in the space provided. Use complete sentences.

1. What is the difference between permanent and washable markers?

2. What is the purpose of chromatography?

3. What is the difference between an acid and a base?

4. What colors make up the color, brown?

Appendix A-9: Grant Supply Request

- Analytical Balance--$1700
- Anti-theft Device--$100
- Vacuum Pump--$210
- Pens and Markers--$100
- Chemicals--$200
- Dyes--$100
- Multi-fibered Ribbon--$21
- T-shirts--$100
- Color Changing Paper--$15
- Resource Books--$200
- Rocks and Minerals--$100
- Art Supplies--$500
- Spectrum Tube Power Supply--$180
- Additional Spectrum Tubes--$150
- Spectrum Charts & Poster--$40
- Color Mixing Apparatus--$875
- Diffraction Grating Materials--$16
- Polarizing Filters--$20
- Prisms--$60
- Color Paddles--$10
- Glo-Sticks--$50
- Phosphorescence Sheets--$50
- Videos--$100
- Computer Software--$200

So far, I have spent approximately $1000 and will be utilizing the rest of the money over the summer months when I have more time to shop around and get the best bargains from the science suppliers. My curriculum will be greatly enhanced with the new supplies, but I do not see any major changes to the labs that have been developed.

APPENDICES B-1 → B-13

Appendix B-1

Vocabulary

Define the following terms and use each one in a sentence.

1. Immiscible

2. Titration

3. Polar

4. Chromatograph

5. Intensity

6. Supersaturated

7. Acid

Appendix B-1 (cont'd)

8. Covalent Bond

9. Pigment

10. Solvent

11. Non-Polar

12. Base

13. Permanent

14. Binder

15. Gem

Appendix B-1 (cont'd)

16. Mineral

17. Mole

18. Solute

19. Concentration

20. Spectrum

Appendix B-2

Color of Gems

After reading the story entitled: The Color of Gems by William S. Harwood, answer the following questions:

1. Why is the gem, *alexandrite,* unusual?

2. How much money is *alexandrite* worth?

3. What is needed to produce the colors in gemstones?

4. What is a red ruby made from?

5. What does ground state mean?

6. What happens when an electron is excited?

7. Why do we see the red color when looking at a ruby?

8. Why are rubies and emeralds similar?

Appendix B-3

Mineral Lab

We are going to investigate the properties of some minerals. Be prepared to share your answers with the class. Observe the following minerals and use the resource books to describe each one in terms of color, texture, appearance, identifying characteristics and common uses.

a) azurite

b) cinnabar

c) halite

d) hematite

e) limonite

f) malachite

Appendix B-3 (cont'd)
Record the physical properties of these minerals according to their characteristics in the chart that follows.

1. Hardness—a number between 1-10 that identifies the ability of a mineral to resist being scratched. Use the Field Hardness Scale to determine the hardness of each mineral.

2. Luster—the way a mineral reflects light from its surface. If light is reflected the way highly polished metals do, it is referred to as a metallic luster. Nonmetallic luster is usually described as brilliant, glassy, pearly, silky and dull to name a few.

3. Streak—the color of the residue scraped off when it is rubbed against a hard, rough surface. Use a piece of unglazed porcelain (also called a streak plate) to determine the color of the streak. Density—the amount of matter in a given space.

4. Density is calculated by dividing the mass by the volume. Research the densities of the minerals.

5. Crystal Shapes—the shape that results from the way the atoms or molecules come together as the mineral is forming. List the crystal shape involved in each mineral.

6. List the elements that make up this mineral

	Azurite	Halite	Hematite	Lapis	Malachite	Limonite
Hardness						
Luster						
Streak						
Density						
Crystal Shape						
Elements in compound						

Appendix B-3 (cont'd)

1. Most of these minerals have been used to give color to paint. List some of the characteristics that would be useful in a pigment of paint.

2. Which metals make up the colorful minerals?

3. How is density determined?

4. What is the density of a 10gram piece of cinnabar that occupies a space of $5cm^3$?

5. What is the difference between a rock and a mineral?

Appendix B-3 (cont'd)

6. How would you go about determining if a yellow pebble is a valuable topaz or a not-so-valuable yellow quartz?

7. What would you do differently from today's lab if you needed to identify a cut and polished gem without damaging it?

8. What is an ore?

9. In general, rubies and emeralds are far more expensive than diamonds. What can you infer from this?

Appendix B-4

Ink Usage Lab

Purpose:

To determine the number of molecules used when writing a message and drinking water.

Materials

1. Sanford's dry erase markers
2. White out board
3. Scale to 3 decimal places
4. Water
5. Cup
6. Four additional writing instruments
7. Calculator

Procedure: Step 1.

1. Obtain a new, *Expo* dry erase marker from the teacher. Determine the mass of the marker and record the initial mass on the observation sheet to the thousandth of a gram.
2. Write the following message on the board. "I like to write pointless messages on the white board with an *Expo* marker in order to know how much ink I use. I will be experimenting with weights that are not felt in my hand, but nonetheless are measurable."
3. Reweigh the marker and record the weight on the observation sheet.
4. Repeat the procedure with three other colors of *Expo* markers
5. Do the calculations on the sheet.

Step 2.

1. Fill a cup with water that you plan to drink. Determine the mass to the thousandth of a gram and record the information on the observation sheet.
2. Drink a mouthful of water.
3. Reweigh the cup and remaining water.
4. Do the calculations on the sheet.

Step 3.

1. Repeat the weighing process with four different types of pens, markers or other writing utensils of your choice. Examples could be your *Papermate* pen, a *Sharpie* marker, a crayon, etc.
2. You will be writing the same message on paper with all four of the experimental writing instruments.
3. Complete the table making sure to name the product tested.

Appendix B-4 (cont'd)
Observation Sheet for Ink Usage Lab

Step 1:

	Color 1 *Expo*	Color 2 *Expo*	Color 3 *Expo*	Color 4 *Expo*
Initial Mass in grams				
Mass After Message				
Expo Ink Used (#1-2)				
Molar Mass of ink	100	100	100	100
Moles of Ink Used (#3/4)				
Number of molecules per mole (Think Avagadro)				
Number of molecules used				

Step 2:

1. Mass of cup full of water initially = _______________g
2. Mass of cup and water after drinking = _______________g
3. Mass of water swallowed = _______________g
4. Molar mass of water = _______________g/mol
5. Moles of water swallowed = (#3/4) _______________mol
6. Number of molecules per mole = (Avogadro would know) _______________ (molecules/mol)
7. Number of molecules swallowed = in scientific notation (#6x7) _______________ (molecules)
8. Number of molecules swallowed = not in scientific notation _______________ (molecules)

Appendix B-4 (cont'd)

	Writer 1	Writer 2	Writer 3	Writer 4
Initial mass in grams				
Mass After Message				
Ink Used				
Molar Mass of Ink	100	100	100	100
Moles of Ink Used				
Number of Molecules per mole				
Number of Molecules Used				

Post lab Questions:

1. How many molecules of water would you swallow if you drank an entire bottle? (540 grams)

2. An *Expo* marker filled with 2.00 grams of ink contains how many moles of ink?

Appendix B-4 (cont'd)

3. An *Expo* marker filled with 2.00 grams of ink contains how many molecules of ink?

4. After using a pen for three weeks, it stopped writing. The initial mass of the pen was 5.12 grams and the final mass was 5.00 grams. How would you determine if the pen malfunctioned or whether it ran out of ink?

5. Compare the data you collected from the experimental pens of your choice and write a paragraph explaining any discrepancies in the expected results to the actual results you obtained.

Appendix B-5

Write To Life Lab

Purpose:

To determine the life expectancy (in meters) and the amount of ink used (in grams) of ten ink pens.

Materials:

1. Write to life roll of paper
2. Computer access to Microsoft Excel
3. Graphing paper.

Procedure:

Today's lab requires a bit of statistical knowledge. We will be using the computers to generate a data sheet and determining the amount of ink that a pen uses over the course of its life. Look at the roll of paper that has been taped on the board. Do you notice globs of ink in spots? How about pens that ran out of ink before their time? Do you notice a regular pattern that formed the circles?

We will be entering data into a table in Excel. We will also be calculating, with the aid of Excel, how much ink is "laid down" (in mg/200M) on the paper based on the weight of each pen. We will also be determining the average life expectancy (in M) of the pens and the average ink used (in g) of the pens.

The following are actual numbers generated from the ink lay down on the roll of paper. The initial masses were:

1) 62.1128	2) 61.8815	3) 61.7479	4) 62.4455	5)62.0081
6) 62.1791	7) 62.1430	8)62.0568	9)62.3362	10) 62.584.6

After 50 meters of ink was deposited on the paper, the pens were re-massed and produced the following numbers:

1) 62.0963	2) 61.8647	3) 61.7327	4) 62.4307	5) 61.9933
6) 62.1623	7) 62.1262	8) 62.0393	9) 62.3202	10) 62.5699

The amount of ink used can be calculated by subtracting the final mass from the initial mass. The number you get will be in grams and will be extremely small. It will need to be converted to mg by multiplying by 1000. Secondly, our goal is to predict how much ink will be used for every 200 meters of lay down so you will need to multiply each of these numbers by 4 for to predict where the ink lay down will be at 200 M. The formula used to calculate the laydown is
[=((B5-C5)*4)*1000]

Appendix B-5 (cont'd)
Another 150 meters of ink (200 total) were laid down and produced the following masses when the pens were reweighed:

1) 62.0451	2) 61.8128	3) 61.6842	4) 62.3852	5) 61.9473
6) 62.1103	7) 62.0749	8) 61.9694	9) 62.2705	10)62.5249

To determine the lay down, repeat the calculations from the initial mass minus the final mass and multiply by 1000. The formula is
[=(B5- E5)*1000]

At 400 meters, the masses were:

1) 61.9764	2) 61.7428	3) 61.6158	4) 62.3234	5) 61.8840
6) 62.0394	7) 62.0074	8) 61.8643	9) 62.2046	10) 62.4651

Calculate the lay down after 400 meters. **[(E5-G5)*1000]**

At 600 meters, the masses were:

1) 61.9086	2) 61.6736	3) 61.5458	4) 62.2596	5) 61.8183
6) 61.9682	7) 61.9361	8) 61.8326	9) 62.1375	10) 62.4034

Calculate the lay down after 600 meters. **[(G5-I5)*1000]**

At 800 meters, the masses were:

1) 61.8828	2) 61.6579	3) 61.5165	4) 62.2148	5) 61.7782
6) 61.9500	7) 61.9103	8) ----------	9) 62.1039	10) 62.3556

Calculate the lay down after 800 meters. Because the product life is shorter than the 800 meters, you need to calculate the lay down by determining the lay down for 200 meters and dividing it by the product life/200.

Each pen ran out of ink before 800 meters. The product life were as follows:

1) 677 M	2) 645 M	3) 685 M	4) 741 M	5) 720 M
6) 649 M	7) 675 M	8) 456 M	9) 700 M	10) 757 M

Your goal is to enter the data in an Excel program. You should be able to enter the data so the computer does your calculations of the lay down test for you. You will also want to know how much ink you used and the life expectancy of each test pen. Set up your spreadsheet following the format on the attached sheet. After your data is in a spreadsheet, graph the lay down verses the distance traveled for each pen.

Appendix B-5 (cont'd)

Write To Life Testing

		50 M		200 M		400 M		600 M		800 M		Product
	Initial wt (g)	wt at 50 M	Laydown	wt at 200 M	Laydown	wt at 400 M	Laydown	wt at 600 M	Laydown	wt at 800 M	Ink Used (g)	Life (M)
1												
2												
3												
4												
5												
6												
7												
8												
9												
10												
Averages												

Appendix B-6

Color In a Saturated Solution

Purpose:
To determine the saturation point of a colored solution and determine how much ink is dispersed in a reservoir of a marker to reach the saturation point.

Materials:

1. Copper sulfate
2. Sodium thiosulfate
3. Distilled water
4. 0.1 gram balance
5. 150 ml beaker
6. 100 ml graduated cylinder
7. Glass stirring rod
8. Test tubes
9. Test tube rack
10. Pencil
11. Ruler
12. Hot plate
13. Small test tubes
14. Colored pencils
15. Empty marker reservoirs
16. Syringe with measurements on the vial

Background:
Intensity refers to the saturation of a color. A chemist knows that a solution is saturated when no more solute can dissolve in a particular volume of solvent. (The dissolving medium in a solution is called the solvent and the substance dissolved in the solution is the solute.) The chemist expresses solution concentration in a quantitative way. One way to express the concentration of a saturated solution is in grams of solute per 100 milliliters of solution. Another way to express concentration is in moles of solute per liter of solution. In a colored saturated solution, the color is at maximum intensity. If the solution is not saturated, the color is less intense because there are fewer colored particles to bring to the eye the wavelengths that are colored.

When a saturated solution of a solute whose solubility increases with temperature is cooled, the excess solute usually comes out of solution, leaving the solution saturated at the lower temperature. But sometimes, if the solution is left to cool undisturbed, the excess solute does not separate and a supersaturated solution is produced. A supersaturated solution may remain unchanged for a long time if it is not disturbed, but once crystals begin to form, the process continues until equilibrium is reestablished at the lower temperature.

Appendix B-6 (cont'd)

In every day terms, have you ever had a glass of iced tea with sugar and found excess sugar at the bottom of the glass? Surely, the sugar dissolves in the tea because the tea is sweeter than unsweetened iced tea. What causes the sugar granules to fall to the bottom is the saturation of the liquid that they are introduced to. Once there is no more room for the sugar to dissolve, it sinks to the bottom of the cup.

Procedure:

Step 1

1. Fill a 150 ml beaker with 100 ml of distilled water
2. Add 5.0 grams of copper sulfate
3. Record and sketch with colored pencils the shade of the solution color on the 2 x 2 square block on your paper.
4. Save 5.0 ml of the solution in a test tube
5. Add 5.0 more grams of copper sulfate to the mixture in the 150 ml beaker
6. Repeat step 3 by recording and sketching the color intensity.
7. Save 5.0 more ml in a second test tube.
8. Continue the process of adding 5.0 grams at a time of copper sulfate to the solution and coloring the intensity each time until the color no longer changes in intensity. At this point, you have reached the saturation point.

Step 2

9. Prepare a saturated solution of sodium thiosulfate by adding in increments of 5.0 grams the solute to hot water.
10. Filter the hot solution
11. Leave the solution cool in an undisturbed place until it reaches room temperature.
12. Drop a small crystal of the sodium thiosulfate into the supersaturated solution. And watch for results.

Step 3

13. Using the syringe with a needle attached, determine how much liquid can be pumped into the reservoir barrel to reach the saturation point for a water-soluble marker. To do this, hold the reservoir upright and inject the needle end of the syringe into the reservoir and release the liquid into the reservoir. Determine how much liquid it takes to fill the reservoir to the saturation point.

Post lab Questions:

1. Calculate the concentration of the saturated solution in grams of solute per 100 milliliters of solvent from Step 1.

Appendix B-6 (cont'd)

2. Calculate the concentration of the saturated solution in moles of solute per liter of solvent from Step 1. (In order to calculate the molarity of the solution, it is necessary to change grams of copper sulfate, $CuSO_4$, to moles. If 5.0 grams of $CuSO_4$ are used, the calculation for moles is 5.0 divided by 159.6 (the mass of one mole of $CuSO_4$) which equals 0.031 mole. If this is dissolved in 100.0 ml of water, the solution is 0.31 M.)

3. What is the difference between a saturated solution and a supersaturated solution?

4. What is the molarity of a HCl solution that contains 10.0 grams of HCl in 250 ml of solution.

5. What role does heat play on the solubility of a solvent?

Appendix B-6 (cont'd)

6. Look at the following table and determine by circling which solutes decrease in solubility with increased temperature

Solubility of Solutes as a Function of Temperature (g/100g H_2O)						
	Temperature (°C)					
Substance	0	20	40	60	80	100
Silver Nitrate	122	216	311	440	585	733
Barium Hydroxide	1.67	3.89	8.22	20.94	101.4	---
Glucose	179	204	238	287	362	487
Calcium Hydroxide	0.189	0.173	0.141	0.121	---	0.07
Cesium Sulfide	20.8	10.1	---	3.87	---	---
Potassium Chloride	28.0	34.2	40.1	45.8	51.3	56.3
Potassium Iodide	128	144	162	176	192	206
Potassium Nitrate	13.9	31.6	61.3	106	167	245
Lithium Chloride	69.2	83.5	89.8	98.4	112	128
Lithium Carbonate	1.54	1.33	1.17	1.01	0.85	0.72
Sodium Chloride	35.7	35.9	36.4	37.1	38.0	39.2
Sodium Nitrate	73	87.6	102	122	148	180
Carbon Dioxide	0.335	0.169	0.0973	0.058	---	---
Oxygen	0.00694	0.00537	0.00308	0.00227	0.00138	0.00

(Adapted from Modern Chemistry, Holt, Rinehart & Winston)

7. What conclusions can you draw about solubility of a solute in a solvent?

Appendix B-7

SOLUBILITY (Solute/ Solvent Interaction)

Purpose:
To understand the polarity of solutions, including inks that are to be tested.

Materials:

1. Turpentine
2. Test tubes
3. Corks or test tube stoppers
4. Plastic pipets
5. Paraffin wax
6. Table salt
7. Mineral oil
8. Isopropyl alcohol
9. Potassium chloride
10. Vegetable oil
11. Sodium bicarbonate (baking soda)
12. Ink samples
13. Glycerol
14. Sulfur
15. Cyclohexane
16. 3 burets
17. 3 ring stands
18. Beakers
19. Clamps
20. Rubber rod (or hard plastic comb)
21. Wool or fur
22. Water

Background:
In the middle of the night of March 24, 1989, an oil tanker by the name of *Exxon Valdez* struck a reef on the Alaskan coast and spilled 11 million gallons of crude oil into the surrounding waters. Petroleum products are insoluble in water so the oil quickly spread across the surface and contaminated over 10,000 square miles of water and hurt 1500 miles of shoreline. Two years later, the Persian Gulf War brought serious environmental damage to major portions of the Middle East. On January 21, 1991, a few days after the Coalition Forces launched an air campaign against Iraq, the Iraqi military forces in Kuwait opened valves at the Sea Island oil terminal near Kuwait City and released large quantities of crude oil into the Gulf, an act of environmental warfare. The oil moved southward and began to accumulate on the north coast of Saudi Arabia, endangering the fragile inter-tidal zones and mangrove forests and destroying wildlife habitats.

In chemistry, we like to say that "like dissolves like" which means that polar solvents tend to dissolve polar solutes and non-polar solvents dissolve non-polar solutes. The two are immiscible which means they do not mix. This is the reason that the oil from the leaking tanker and the oil terminal did not mix with the seawater and were able to spread across a greater surface area.

In every day terms, you have probably noticed that oil doesn't mix with the vinegar in salads and requires shaking prior to use. Sap from trees and tar are a few other examples of sticky substances that need a non-polar solvent to remove them because they do not wash off with soap and water. Turpentine or a similar alcohol-based solvent works well to remove non-polar stains because it is non-polar. Industry develops solvent-based products regularly. The "permanent" markers, like *Sharpie*™ are developed based on their inability to dissolve in water and are used for many different applications.

In order to develop caffeine free products, chemists learned when seeds from cola and coffee or leaves from tea are soaked in methylene chloride (CH_2Cl_2), the caffeine dissolves, leaving the other compounds behind. This technique worked great until consumers worried about the adverse effects of the methylene chloride. Realizing that "like dissolves like", chemists sought a non-polar molecule to dissolve the non-polar caffeine molecules. Chemists perfected a way to subject the leaves or seeds to highly pressurized liquid carbon dioxide. They found that carbon dioxide penetrated plant tissue and dissolved the caffeine while leaving the flavor component behind.

Knowing that "like dissolves like," it is possible to determine the polar nature of various substances. Polar substances show obvious signs of dissolving in water (a polar solvent), but not in turpentine (a non-polar solvent), while non-polar substances do just the opposite. This is also true for polar and non-polar molecules and their ability to bond covalently.

When two atoms have an even distribution of electrical charge, they are considered non-polar covalent bonds. The electrical charge corresponds to a balance in nature. Polar covalent bonds have an unequal attraction for the shared electrons. If you have ever experienced a phenomenon called "static cling" then you have dealt with polar covalent bonding. The clothes that stick to each other coming out of the clothes dryer occur because electrons accumulate on one material at the expense of another so that one material obtains a net negative charge and the other has a net positive charge. Your hair acquires a positive charge when you comb or brush it. The comb is picking up the electrons and creating a situation where your hair can stand on end.

Procedure:

1. Set up three ring stands with clamps that hold the burets.
2. Fill each of the three burets. One with isopropyl alcohol, another with water and the third with cyclohexane.
3. Rub the rubber rod or plastic comb repeatedly with wool or fur.

Appendix B-7 (cont'd)

4. Open the stopcock of the buret containing water and allow it to drain into a beaker.
5. Move the comb or rod close to the stream of water and observe to see if it is attracted to the electrostatic field of the comb.
6. Repeat the process with the cyclohexane and the isopropyl alcohol.
7. Fill a row of test tubes with water and another with turpentine.
8. Determine the polar nature of each of the items listed in Table 1 by testing their solubility in the two solvents.

Table 1: Polar or Non-polar?

Items to be tested	**In Water** *(Polar Solvent)*	**In Turpentine** *(Non-polar Solvent)*	**Polar or Non-polar**
Paraffin Wax, *(C_nH_{2n+2})*			
Table Salt *($NaCl$)*			
Mineral Oil			
Isopropyl Alcohol *($CH_3CHOHCH_3$)*			
Potassium Chloride *(KCl)*			
Toluene *($C_6H_5CH_3$)*			
Baking Soda *($NaHCO_3$)*			
Ink #1			
Ink #2			
Ink #3			
Ink #4			
Glycerol *($C_3H_5(OH)_3$)*			
Sulfur *(S)*			

(adapted from Hands On Chemistry Activities with Real Life Applications)

Answer the following questions:

1. What is the rule of thumb for predicting whether one substance will dissolve in another?

Appendix B-7 (cont'd)

2. On the basis of your results, define polar and non-polar solutes.

3. For centuries, sailors used "pitch" to seal the planks on wooden boats. Pitch is a sticky resin produced by cone bearing trees to protect them from insect and fungal attack. When a limb is broken or the bark is ruptured, the tree releases the pitch resin to seal the wound. Explain why pitch would work well as a sealant.

4. Look up the definitions of polar and non-polar covalent bonding on page 162 and describe the bonding attraction in terms of molecules in the solvents.

5. Some art instructors recommend that students clean brushes and hands with a vegetable oil or mineral oil in order to reduce exposure to organic solvents. Would the oils be more effective removing water-based paints or oil-based paints?

Appendix B-7 (cont'd)

6. What chemical property must sun block lotion have if it is waterproof (won't wash of when you go swimming)?

7. Would you use a polar or non-polar solvent to clean the ink cartridge from the printer when it clogs up with ink residue from lack of use?

8. Explain why ethanol will dissolve in water and carbon tetrachloride will not.

Appendix B-7 (cont'd)

Polarity of Molecules

Determine whether the following molecules are polar or non-polar. The key is in their Lewis dot structures.

1. N_2	2. HF
3. H_2O	4. CH_3OH
5. CO_2	6. H_2S
7. NH_3	8. I_2
9. CH_4	10. $CHCl_3$
11. SO_3	12. O_2

(adapted from Chemistry Reproducible Activities)

Appendix B-8

Pigment Colors and Spectra Lab

Refer to the spectrum given off by the white light traveling through the prism.

1. How many distinct colors can you see in the spectrum?

2. Are the widths of each of the bands of color the same?

3. Can you tell where the yellow ends and the green begins?

Use only the three primary colors to replicate the colors of the spectrum, in order, as best you can on a piece of plastic. You will want to vary the color combinations from 100% primary colors to incorporate the secondary and intermediate colors.

Questions:

1. Approximately how much of each primary color did you use to replicate each color of the spectrum?

R	O	Y	G	B	I	V
r	r	r	r	r	r	r
y	y	y	y	y	y	y
b	b	b	b	b	b	b

1. Were there any colors that were difficult to produce? Which ones?

2. Did you see a pattern in making the intermediate colors? Explain.

3. Were there any colors that didn't seem to fit into a similar pattern? Explain.

Appendix B-8 (cont'd)

4. Describe what you see when you look at the light spectrum and your pigment spectrum through each of the colored plastic samples. Describe any changes you see in the colors for each of the filters.

Use your knowledge from the paint combinations in the spectrum to develop a match to the color on the paint swatch provided by your teacher using the primary colors. You will be given an additional sample of white paint in case you need to change the value of the color.

1. State Planck's equation of light energy in words and write the equation too.

2. The blue pigment will reflect blue light and absorb all the rest of the colors. If the blue light has a frequency of 7.0×10^{14} what is its wavelength and energy?

3. When you get an X-ray, it will have a wavelength of 2.0×10^{-9} meters. How much energy does it have?

Appendix B-8 (cont'd)

4. Compare the energy of the X-ray to the energy from the blue light in the last question.

5. Find another lab group that has a spectrum similar to yours. Compare the amount of primary colors each of you used. What conclusions can you draw from your spectrum? Account for any differences.

6. Change the amounts of colors used to produce more intermediate colors that fall between the colors that you produced in the first spectrum of the rainbow. What is the maximum number of colors you can produce?

Appendix B-8 (cont'd)

Write a paragraph about the visible light spectrum and how it relates to waves. Look in your textbook and explain how other waves fit into the spectrum and how we know this information.

Appendix B-9

Developing Pigment Lab

Purpose:
To prepare various pigments as a prelude to the development of inks and paints for future use in the classroom

Materials:

1. 5.0 g calcium chloride
2. 8.0 g sodium carbonate
3. 3.0 g ammonium iron (III) sulfate (a.k.a. ferric ammonium sulfate)
4. 3.0 g potassium hexacyanoferrate (II)
5. 4.0g zinc nitrate
6. 3.5 g potassium chromate or 4.0 g sodium chromate
7. 5.0 g nickel sulfate
8. 1% dimethylglyoxime solution
9. 6.0 g cobalt chloride
10. 3 ml sodium silicate solution
11. 6 ml glycerol
12. Powdered charcoal
13. Water
14. Balance sensitive to 0.01 g
15. Thick-walled Pyrex test tube (about 12- to 15-mm by 150-mm) with cap or stopper
16. Test-tube holder
17. 250-mL or larger beaker
18. Mortar and pestle
19. Funnels
20. Filter paper
21. Film canisters
22. Disposable pipets

Background:
Inks and paint are composed of three principle components: a pigment or dye that supplies the desired color, a binder that hardens to form a continuous film over the surface, and a volatile solvent that evaporates in the curing or hardening process. Other components may be added to improve the wetting ability, smoothness, aroma etc. The following are typical additives:

1) Thickeners—improve consistency of the wet paint or ink
2) De-foamers—help break foam formed by agitation or application
4) Anti-skinning agents—prevent formation of skin on the paint in the can
5) In-can preservatives and fungicides—kill organisms that might grow in the wet paint or ink during storage
6) In-film preservatives and fungicides—kill organisms that might grow in the cured paint film or on the inked surface
7) Driers—improve the drying rate of the paint or ink

Appendix B-9 (cont'd)

To Prepare Pigment:

1. Heat about 400 ml of distilled water in a 500 ml beaker on a hot plate; keep it warm (at about 45-50°C) at all times.

WHITE pigment

1. Place 5.0 grams of calcium chloride in a 20 x 150 mm test tube. Fill the tube half full of warm water. Stopper the tube and shake it gently until the calcium chloride dissolves.
2. Add 5.0 grams of sodium carbonate to the tube.
3. Stopper the tube and invert. DO NOT SHAKE.
4. Remove the stopper to release the pressure caused by the evolution of carbon dioxide.
5. Mix thoroughly.
6. Filter the solution through a clean filter paper. Clean out the test tube using distilled water over the filter paper in order to collect the precipitate.
7. Repeat this procedure 3 times in order to triple the batch of pigment.
8. Allow the precipitate to dry overnight.
9. Transfer to a small plastic film canister.

BLUE pigment

1. Place 3.0 grams of ammonium iron (III) sulfate (also called ferric ammonium sulfate) in a 20 x 150 mm test tube and fill the tube half full of warm water. Stopper and shake the tube until the salt dissolves.
2. Place 3.0 grams of potassium hexacyanoferrate (II) in a test tube and fill one third full of warm water. Shake to dissolve.
3. Add the solution to the first test tube.
4. Invert the mixture.
5. Filter off the suspension as you did for the white pigment
6. Repeat the procedure 3 times
7. Dry and transfer to film canister

YELLOW pigment

1. Dissolve 4.0 grams of zinc nitrate in a test tube one third filled with warm water.
2. Dissolve 3.5 grams of potassium chromate or 4.0 grams of sodium chromate in a second test tube one third filled with warm water.
3. Add this solution to the first test tube
4. Stopper, invert to mix the solutions
5. Filter and transfer
6. Repeat to triple the batch

Appendix B-9 (cont'd)

RED pigment

1. Dissolve 3.0 grams of nickel sulfate in a test tube half filled with water.
2. Add 1% dimethylglyoxime solution until the test tube is slightly more than three fourths full
3. Stopper, shake and filter
4. Triple the batch

ROYAL BLUE pigment

1. Dissolve 3.0 grams of cobalt chloride in a test tube half filled with warm water.
2. Add 3mL of sodium silicate solution
3. Shake, filter
4. Triple the batch

LAVENDER pigment

1. Dissolve 3.0 grams of cobalt chloride in a test tube half filled with water.
2. Add 3.0 grams o sodium carbonate.
3. Stopper and invert tube. DO NOT SHAKE
4. Remove the stopper to release the pressure caused by the evolution of carbon dioxide
5. Filter and save.
6. Triple the batch

BLACK pigment

1. Add powdered charcoal (bone black) to the white after it is developed.

All pigments need to dry overnight so a dry block of powder forms. You will use the mortar and pestle to grind the dry pigment into a fine powder for future use.

Appendix B-9 (cont'd)

Write a paragraph about the development of the various colors of pigment you created. Include information about the chemicals used and whether these were single placed reactions, double placed reactions or synthesis reactions. Also, explain what a pigment is and what else is needed in order to develop the paints and inks.

Appendix B-10

Making Ink and Paint as a Surface Coating

Purpose:
To prepare a non-aqueous surface coating by using various pigments with an organic solvent and a binder

Materials:
1. 2-5 ml linseed oil
2. 4-10 ml turpentine
3. Eggs
4. Karo syrup
5. Milk
6. Gum Arabic
7. Glycerol
8. Water
9. Liquid dish soap or hand soap or Alconox granules
10. Balance sensitive to 0.01 g
11. Thick-walled Pyrex test tube (about 12- to 15-mm by 150-mm) with cap or stopper
12. Test-tube holder
13. 250-mL or larger beaker
14. Mortar and pestle
15. Fountain pens
16. Small, artistic paint brushes
17. Plastic spot plate or soufflé dish
18. Glass spot plates
19. Film canisters of pigment
20. Disposable pipets

Background:
Inks and paints are classified into two groups: oil-based or water based. The intended use, surface it is meant to cover and longevity help determine which binder properties are used in the inks and paint. Oil based products were once the most common, but new technology has changed the consumer preferences toward water based binders due to the ease in clean up. Latex is a synthetic polymer that serves as a binder that emulsifies with water that evaporates when the paint is spread. The latex forms a tough polymeric film that covers the surface. Similarly, linseed oil is often used as a binder in oil-based products. When the paint is spread, the linseed oil molecules come together and polymerize to form a tough film over the surface. The basic concept for oil-based and water based inks is the same and pigments are added to both types of media. They differ in drying times as people want ink to be quick drying and smudge resistant.

Appendix B-10 (cont'd)
To make paint or ink, you need a medium to carry the pigment. The medium should be a liquid that will evaporate leaving the pigment behind to change over time into a solid, trapping the color on the surface. Some of the media currently used are oil, water, acrylics, egg and milk. Each one of these media have advantages and disadvantages that range from drying times to intended surfaces for the paints and ink. We will make a variety of paints and inks and determine which ones work best for a given project.

To Prepare Colored Inks and Paints:

Oil Based

1. Measure 2 g of each pigment on the scale and place each one in a soufflé dish
2. Add 2 ml of linseed oil and 4 ml turpentine to each pigment color
3. Add more pigment and/or linseed oil/ turpentine until you get a desired level of color. Make sure you keep account of how much of each product you are using. Make a variety of colors.
4. Record your recipe in the following table:

Pigment	Linseed Oil	Turpentine	Pigment
White			
Yellow			
Red			
Blue			
Lavender			
Black			

Water Based

1. Measure out 6 g of gum Arabic (a.k.a. Acacia) and place in a small beaker
2. Add 18 ml of water.
3. Add 10 drops of liquid dish soap
4. Thoroughly stir the mixture.
5. Add 1/6 of the solution to each 2 g sample of pigment colors to have an array of watercolors.
6. If needed, add more pigment, water or gum arabic until a desired level of color is reached.
7. Record your recipe in the following table:

Pigment	Acacia	Water	Dish Soap
White			
Yellow			
Red			
Blue			
Lavender			
Black			

Appendix B-10 (cont'd)

Glycerin Based

1. Mix 1 ml Karo syrup with 15 ml water
2. Add 6 ml of glycerol
3. Add 6 g gum Arabic
4. Add 2-3 granules of Alconox or liquid dish soap
5. Mix well
6. Use a pipet to dispense 1-2 ml of the product to each of the pigments.
7. Record your recipe in the following table.

Pigment	Karo Syrup	Glycerol	Gum Arabic	Dish Soap
White				
Yellow				
Red				
Blue				
Lavender				
Black				

Tempura Paint

1. Crack an egg and separate the white albumin from the yolk.
2. Dispose of the albumin.
3. Mix the yolk with the pigment colors to form paint.
4. Repeat the process with milk
5. Record your recipe in the following table

Pigment	Egg	Milk
White		
Yellow		
Red		
Blue		
Lavender		
Black		

Use the fountain pen and paintbrush to draw a picture, write a message, answer the questions, etc. making sure to use all the colors of ink that you developed. You are to assess the quality of each media and determine whether they make good quality inks or paint. You also need to test some of the products on wood and plastic to see if they might adhere better there as opposed to paper.

Appendix B-10 (cont'd)
Post-lab Questions:

1. Place a drop of each paint or ink in the appropriate box.

	Oil Based	Water Based	Glycerin	Tempura
White				
Blue				
Yellow				
Red				
Royal Blue				
Lavender				
Black				

2. Based on the initial outcome, rate the media for use on paper. Which one worked the best? Worst?

(adapted from Hunter, Paul W., Lab Enrichment Activities Program, Spring 1993)

Appendix B-11

Paper and Fabric Chromatography

Purpose: To show ink separation techniques with water based and solvent based inks.

Materials:

1. Several brands and colors of water-soluble markers (Vis-à-Vis, Expo and Colorific Retractables work very well). Try to include black, brown, and green.
2. Several different colored permanent markers (such as Sharpie, El Marko, PaperMate M15) including at least one of green, purple, or black.
3. Filter paper in various sizes
4. Squares of old white sheets, white T-shirt material, or muslin large enough to fit over the mouth of the container. Socks work well.
5. Glass, plastic or metal wide-mouthed containers (plastic can be used only if acetone is not used)
6. Large rubber band that will stretch around the circumference of the container
7. Scissors
8. Two adhesive labels (or paper and tape to make your own)
9. Water
10. Rubbing alcohol (70% isopropyl alcohol) or acetone-based nail polish remover

Background:
We like to make colors an important part of our lives so manufacturers make products in a variety of colors. Have you ever wondered how these colors are created? We see a myriad of colors all around us, and many of them result from a mixing or blending of other colors. Markers are a prime example of something colorful we commonly use. A single color of marker may contain many different pigments. You can probably make some guesses as to what colors of pigments are contained in marker colors such as green, orange, and purple, but how about black and brown? Have you ever washed a red and white shirt and had the red dye run onto the white? Sometimes this bleeding of colors can have a positive outcome. Try this exploration to create some intentional bleeding to see for yourself. You may be surprised by your colorful results.

Procedure:

1. Paper Chromatography—Fold the round filter paper in half a few times in order to find the center of the circle. Cut the tip off of the filter paper making sure the hole in the center is small. You should make a few of these.

Appendix B-11 (cont'd)

2. Ink dots--Place different colors of ink dot (about 1/2 cm in diameter) on each folded section of the circle, about 1 cm from the hole. You want to be able to readily compare the pie shaped wedges when you are done.
3. Label one container "water" and the other either "isopropyl alcohol" or "acetone," depending on which one you are using. (Do not use acetone if you are using plastic.) Pour about 1/2 cm of each solvent into the appropriately labeled container.
4. Make a siphon funnel out of a scrap piece of filter paper that will be inserted into the hole and will settle into the solvent. This will bring the solvent to the paper through a capillary action. Make sure not to let the ink dots touch the solvent directly. (If the solvent level touches the dots, pour out some of the solvent and prepare another filter paper with ink dots.)
5. Allow the chromatograms to develop until the solvents are about 1 cm from the edge of the paper. Remove the circles. Use a pencil to write the solvent used on the dry part of each circle. Now compare the chromatograms and describe how they are alike or different.

Cloth:

1. Stretch a piece of cloth over the open end of the container and loop a rubber band around the sides to secure the material. Near the center of the cloth, create a circle (about the circumference of a quarter) of different colored dots. Record the color and position of each dot.
2. While the ink dots are still wet, drip several drops of water in the center of the circle of dots so that the water travels out radially to the dots.
3. Repeat with a second piece of cloth, this time with the dots dry, and record what happens.
4. Allow the cloth to dry almost completely, or set up a third piece of cloth as you did in Step 1.
5. Drip rubbing alcohol in the center of the circle of dots so that the liquid travels out radially to the dots. Let the fabric dry out between additions of the rubbing alcohol.
6. On another piece of cloth, dot several colors over one spot and drip rubbing alcohol onto the spot.
7. You can also apply this technique to drawing lines. By now, you should have a grasp of a design you would like to see. Try it and see the results.
8. When you are done, clean up your area before answering the lab questions.

Appendix B-11 (cont'd)

Answer the following questions:

1. What does this lab indicate about the two solvents?

2. What is happening to the ink dots when they are wet? Explain in terms of attraction.

3. What happens to the ink dots when they are dry? What does this tell you about the ink pigment?

4. Describe the various colors that make up the green, purple, black and brown.

Appendix B-11 (cont'd)

5. If a paper chromatogram of a red dye shows a smear of pink, is this conclusive evidence that the dye is a mixture? Explain.

6. What is the difference between a permanent and a washable marker?

7. Explain any differences between the observations with water and with rubbing alcohol.

8. What is the difference between bleeding and chromatography, and what factor is most likely to determine which one occurs?

Appendix B-11 (cont'd)

9. Indicate color blends to develop each marker.

	Black	Brown	Purple	Green
Vis-à-vis				
Expo				
Colorific				
Sharpie				
Papermate				
El Marko				

(adapted from NSF-funded General Chemistry: Discovery Based Advances)

Appendix B-12

Acid/Base Reactions

Purpose:
To discover acid/base chemistry through color with the use of color changing markers, disappearing ink and titration.

Materials:
1. Crayola™ color changeable markers
2. Thymolphthalein indicator
3. Sodium hydroxide solution
4. Sodium bicarbonate
5. Hydrochloric acid
6. Phenolphtalein indicator
7. Methyl orange solution
8. Alconox soap
9. Erlenmeyer flasks
10. 2 Burets
11. Ring stand
12. 2 sided clamp
13. Beakers
14. White paper
15. Ammonia
16. Eyedropper
17. pH paper

Background:
When you buy a set of color changing markers, you have the option of using them as their initial color or to change their color from one to another. How does chemistry affect this process? What is in the color- changing marker that causes the change? Have you ever written a message with disappearing ink? Did you ever wonder what is happening when magic shows are able to produce color variations to dazzle the audience? They pretend it is magic, but we all know, they are using simple chemistry.

In today's lab, you will be moving from station to station performing different activities that all tie in to one basic theme—acid/base chemistry.
Acids were first recognized as a distinct class of compounds because of their common properties in aqueous solutions. They include:
1. Sour taste (Don't taste this)
2. Change color of acid/base indicators
3. React with metals to release hydrogen gas
4. React with bases to produce salts and water
5. Conduct electrical currents

An Arrhenius acid is a chemical compound that increases the concentration of hydrogen ions (H^+) in an aqueous solution.

Appendix B-12 (cont'd)

Bases share some similar properties with acids, but are different in that they:

1. Taste bitter (Don't taste this either)
2. Change colors of acid/base indicators
3. Feel slippery
4. React with acids to produce salt and water
5. Conduct electrical currents

An Arrhenius base is a substance that increases the concentration of hydroxide ions (OH^-) in aqueous solution.

Expressing acidity or basicity in terms of the concentration of H_3O^+ (hydronium ions) or OH^- (hydroxide ions) can be cumbersome because the values tend to be very small. A more convenient quantity representation is pH. When something has a high pH, it is very basic. When looking at acids and bases, there is a chart that indicates alkalinity and acidity of common household products. The scale ranges from 0-14 with 7.0 being the neutral area. Pure water has a pH of 7.0. Acids have a pH that is less than 7.0 where bases have a pH that is higher than 7.0. In order to neutralize a solution, basic solutions are treated with acid and acidic solutions are treated with bases.

Titration is the controlled addition and measurement of the amount of a solution of known concentration required to react completely with a measured amount of a solution of unknown concentration. If the concentration of one solution is known precisely, the concentration of the other solution in a titration can be calculated from the chemically equivalent volumes. Because acids and bases react, the progressive addition of an acid to a base (or a base to an acid) can be used to compare the concentrations of the acid and base.

Procedure: (Stations do not have to be completed in order)

Station 1

1. On a sheet of white paper, draw a picture with each of the colors from the set of markers.
2. Draw lines through your picture with the color change marker to produce twice as many colors as the original markers produced.
3. Now place drops of ammonia on some of the original colored lines, a safe distance away from where you used the color change markers.
4. You should notice that adding ammonia produces the same color change as drawing with the color change marker.

Station 2

1. Write a message on white paper with the sodium hydroxide solution using the q-tips.
2. Spay the squirt bottle with the thymolphthalein indicator onto the dry message and read.
3. Make a mystery card with a message that "Dear mom" can read when she shows up for parent–teacher night. In the message, I want you to

Appendix B-12 (cont'd)

explain how the chemistry of this reaction works. Use the following words in your message: Acid, base, indicators, pH,

Station 3

1. In the tray, add approximately 150ml of tap water to a 1-L beaker
2. Add 25g sodium bicarbonate to the beaker
3. Add 25 g Alconox to the beaker and stir (All solids may not dissolve)
4. Add 50 ml of 0.5% solution methyl orange indicator to the beaker containing the sodium bicarbonate and Alconox. Stir (the resulting solution should resemble orange juice)
5. To the 300 ml beaker, add approximately 135-140 ml of 3 M hydrochloric acid
6. Place the original beaker with the "orange juice" in the center of the tray
7. Wearing safety glasses, quickly, but carefully, add the 140 ml of hydrochloric acid all in one pour to the beaker containing the orange mixture
8. Stand back and watch the orange juice turn to a strawberry float.

Station 4

1. Using the set-up provided, determine which of the burets will be used for acid and which one for the base. Rinse out the acid buret with the hydrochloric acid three times with the acid you will be using for the titration.
2. Repeat the procedure for the base buret with the base solution of sodium hydroxide.
3. Fill the first buret to a point above the calibration mark with the acid of unknown concentration.
4. Release some acid from the buret into a small beaker to remove any air bubbles and lower the volume to the calibrated portion of the buret.
5. Record the reading at the top of the acid in the buret to the nearest 0.01 ml as your starting point.
6. Release 10 ml of hydrochloric acid into a clean Erlenmeyer flask.
7. Subtract the current volume reading on the buret from the initial reading. This is the exact volume of hydrochloric acid released into the flask. Record to the nearest 0.01 ml
8. Add three drop of phenolphthalein to the Erlenmeyer flask.
9. Fill the other buret with the sodium hydroxide solution to a point above the calibration mark.
10. Release some base from the buret into a beaker to remove any air bubbles and to lower the volume to the calibrated portion of the buret.
11. Record the reading at the top of the base to the nearest 0.01 ml as your starting point.
12. Place the Erlenmeyer flask under the base buret so the tip of the buret extends into the mouth of the flask.

Appendix B-12 (cont'd)

13. Slowly release base from the buret into the flask while constantly swirling the contents of the flask. The pink color should fade with swirling.
14. The titration is nearly at the end point when the pink color stays for longer periods of time. At this point, add base drop by drop.
15. The equivalency point is reached when a very light pink color remains after 30 seconds of swirling.
16. Subtract the current volume reading on the buret from the initial reading. This is the exact volume of the base released into the flask. Record it to the nearest 0.01 ml.

Post-lab Questions:

1. What is the difference between an acid and a base?

2. Upon your observations, explain the orange juice turning into a strawberry shake. Use the following terms in your explanation: Acid, base, indicator, pH.

3. What is the purpose of running a titration?

Appendix B-12 (cont'd)

4. Look up in your textbook the definitions of the following terms and compare and contrast their meaning.

    - Arrhenius acid

    - Bronsted Lowry acid

    - Lewis acid

Appendix B-13

Emission Spectroscopy Lab

Purpose:
To evaluate how our eyes adjust to different wavelengths of light to see color and to learn about elements capabilities to show color.

Materials:
1. Spectroscope
2. Incandescent Light
3. Plant Grow Light
4. Fluorescent Light
5. Ions of Li^{+}, Na^{+}, K^{+}, Ca^{++}, Sr^{++}, Cu^{++}
6. Ethyl Alcohol
7. Glass Watch Plates
8. Bunsen Burners
9. Copper Wire

Background:
The ability to see light is a form of electromagnetic radiation. All forms of electromagnetic radiation travel at a constant speed of 3.0×10^{8} m/s and in the form of waves and frequencies. Because wave motion is repetitive in nature, the colors that we see are measurable and mathematically calculated to fall within the range of 400nm to 700nm. The wavelengths are inversely proportional to the frequency. In other words, the wavelength of light decreases as its frequency increases.

Light is capable of knocking loose electrons from metal. The lowest energy state of an atom is known as the ground state. When the atom moves to a higher energy state, it is excited. When an excited atom returns to the ground state, it gives off energy in the form of colored light. Multiple oxidation states for various elements are quite common and color is an indication of different oxidation states. For example, what is the color of copper? If you answer blue or gold, you are right. Looking at the periodic table, you will see that copper has an oxidation of +1 and +2. The strength of the electron field determines whether the electrons pair up in the lower energy levels or whether they have the energy to occupy higher levels before pairing up. Photons are absorbed in the region between the two energy levels resulting in a variety of color for elements in compounds. The intensity of the negative charge determines the separation space between energy levels. In other words, when there is a low spin energy, the electrons pair up in the lower energy levels, but with a high spin, the electrons occupy the higher energy level as single electrons before pairing up.

Procedure:
Pay close attention to the number and amount of each color you see. Record your observations in the indicated space. Do not stare directly into the light.

Appendix B-13 (cont'd)

1. Use your student spectroscope to examine the light emitted by a low wattage incandescent light source. Describe what you see.

2. Use your spectroscope to examine the light given off by the fluorescent light. How does the light you see this time differ from the light given off by the incandescent bulb?

3. Use your spectroscope to examine the light given off by the plant grow bulb. Record your observations.

When metal compounds are heated they will give off distinctive colors. These colors will show up as lines when you use your spectroscope. Show the colors that each of these compounds gives off as accurately as possible. Identify the unknown mixture of salts by their spectrum.

compound	metal ion	violet	blue	green	yellow	orange	red
	Li^{+}						
	Na^{+}						
	K^{+}						
	Ca^{++}						
	Sr^{++}						
	Cu^{++}						
Unknown							

Appendix B-13 (cont'd)

1. Describe the difference between the colors given off by the incandescent bulb and the fluorescent bulb.

2. Describe how the light given off by a heated compound can be used to identify the metals.

3. The longest wavelength of light that you can see is about 700 nm. What is the frequency of this light?

4. How much energy does a photon of this light have?

5. Where does the energy come from in the spectrum?

6. Why would only certain colors showing up for each metal help you understand the atom?

Appendix B-13 (cont'd)

7. Minerals can give off light if they are exposed to ultraviolet light. This is called fluorescence. They can glow for a long period of time. This is known as phosphorescence. Some mineral will glow when heated. This is called thermoluminescence. Triboluminescence is when minerals give off light when struck or crushed. Explain some possible processes that would explain how these minerals give off light.

BIBLIOGRAPHY

BIBLIOGRAPHY

Barth, Roland. Teacher Leader. *Phi Delta Kappan*, February, 2001. p. 3

Ibid. p. 5

Ibid. p. 6

Ibid. p. 10

Chemistry Reproducible Activities. 2002.

Clark, G., and Riley, W., The Connection Between Success in a Freshman Chemistry Class and a Student's Jungian Personality Type. *Journal of Chem Ed.* December, 2001. p. 1406

Davis, Raymond, et al. Modern Chemistry. *Holt, Rinehart and Winston.* 1999

DeBruyn, Robert. What We've Learned About How Students Learn. *The Master Teacher.* vol. 33, #20. 2002.

Ibid. Awakening The Creativity In Students. *The Master Teacher.* Vol. 33, # 17. 2002.

Denio, Allen. The Joy of Color in Ceramic Glazes with the Help of Redox Chemistry. *J Chem Educ.* October,2001. p. 1304

Fitzell, Susan Gingras. Successful Inclusion Strategies and Techniques for Adapting Curricula to Meet IEP Requirements for Mild to Moderate Special Needs Students. *Bureau of Education & Research.* 2001.

Freemantle, Michael. Chemistry, Color and Art. *Chemical and Engineering. News.* February, 2001. p. 50

Flinn Chem Fax. Orange Juice to Strawberry Float. 2002. unpublished.

Ginott, Haim. Between Teacher & Child, A Guide Book For Parents and Teachers. September,1993. p. 51

Greenberg, B. & Patterson, D. Art in Chemistry, Chemistry in Art. *Teacher Ideas Press,* Colorado, 1998

Harwood, William, The Color of Gems. *Chem Matters.* December,1988. p. 7-9.

Haslett Public Schools Graduation Requirements. (2004). Unpublished.

Herr, N. & Cunningham, J. Hands On Chemistry Activities with Real Life Applications.

Hunter, Paul. Lab Enrichment Activities Program, Spring 1993.

Hutton, Bill. Iowa State University. *Journal of Chem Ed.,* February, 1984.

Knoespel, Sheldon. Michigan State University. Chemical Demonstrator. 2002.

Lansing State Journal and Michigan Department of Treasury, High School MEAP Test Scores.

Larochelle, et al. Michigan Alternative Education Study. 1998 Study of the Status of Alternative Education in the State of Michigan. *Executive Summary,* January 1999.

Lehr, Judy Brown. At-Risk, Low Achieving Students In The Classroom. *National Education Association of the United States,* 1988.

Meridian High School Brochure. 2002. Unpublished.

Meridian High School Staff Handbook. 2003. Unpublished.

Moore, J. W. Science and Art. *Journal of Chem Educ.* October, 2001, p. 1295

NSF-funded General Chemistry, Discovery-Based Activities

Physical Science Reproducible Activities (1998)

REMC- Video-Color

Todd, David and Davis R. Logic in the Laboratory *from "Acid and Water: A Socratic Dialogue," Journal of Chem Ed and Modern Chemistry.* 1999. p. 463.