

## **BETTER LIVING THROUGH CHEMISTRY: COLOR MY WORLD**

Age Group: High School, 9-12th grade  
Course: Chemistry, Physical Science  
Duration of Investigation: 5 Days – on a 90 minute block schedule

### **I. BACKGROUND**

One of the first things covered in this course, after classroom rules, procedures and lab safety is, “Why are we studying this subject?”, “What is Chemistry?”, “What can you do with it?” and “When am I ever going to use this stuff?” Well, there are many areas of chemistry and this investigation is intended to be an introduction to a few areas of chemistry and the possible professions in those fields such as: textile chemistry, materials engineer, polymer chemistry, organic chemistry, biochemistry, and inorganic chemistry. It’s also meant to review the scientific process and thinking skills I wish to instill in my students - questioning, observing, problem solving, developing a plan, investigation, analysis, incorporating more writing in class and creativity. As for the “academic” portion of this investigation that is directly governed by the Georgia Performance Standards (GPS), I plan to discuss the following concepts: solutions (including solvent and solute, concentration, saturation, acids, bases, salts and pH) and color (how we perceive color, reflection, electromagnetic spectrum, photons, wavelengths and chromatography). A natural and imbedded extension is to include cross-curricular areas to show my student the overlap or inter-connectedness science has with other subjects; in this specific investigation that would include history and the social sciences, fine arts and biology.

### **II. LESSON GOALS/GPS**

This investigation will cover the following Georgia Performance Standards:

#### **Characteristics of Science**

**SCSh1** Students will evaluate the importance of curiosity, honesty, openness, and skepticism in science.

- a. Exhibit the above traits in their own scientific activities.
- b. Recognize that different explanations often can be given for the same evidence.
- c. Explain that further understanding of scientific problems relies on the design and execution of new experiments which may reinforce or weaken opposing explanations.

**SCSh2** Students will use standard safety practices for all classroom laboratory and field investigations.

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- a. Follow correct procedures for use of scientific apparatus.
- b. Demonstrate appropriate techniques in all laboratory situations
- c. Follow correct protocol for identifying and reporting safety problems and violations.

**SCSh3** Students will identify and investigate problems scientifically.

- a. Suggest reasonable hypotheses for identified problems.
- b. Develop procedures for solving scientific problems.
- c. Collect, organize and record appropriate data.
- d. Graphically compare and analyze data points and/or summary statistics.
- e. Develop reasonable conclusions based on data collected.
- f. Evaluate whether conclusions are reasonable by reviewing the process and checking against other available information.

**SCSh6** Students will communicate scientific investigations and information clearly.

- a. Write clear, coherent laboratory reports related to scientific investigations.
- b. Write clear, coherent accounts of current scientific issues, including possible alternative interpretations of the data.
- c. Use data as evidence to support scientific arguments and claims in written or oral presentations.
- d. Participate in group discussions of scientific investigation and current scientific issues.

**Content for Physical Science**

**SPS6** Students will investigate the properties of solutions.

- a. Describe solutions in terms of: solute/solvent, conductivity, concentration
- b. Observe factors affecting the rate a solute dissolves in a specific solvent.
- c. Demonstrate that solubility is related to temperature by constructing a solubility curve.
- d. Compare and contrast the components and properties of acids and bases.
- e. Determine whether common household substances are acidic, basic, or neutral.

**SPS9** Students will investigate the properties of waves.

- a. Recognize that all waves transfer energy.
- b. Relate frequency and wavelength to the energy of different types of electromagnetic waves and mechanical waves.
- d. Investigate the phenomena of reflection, refraction, interference, and diffraction.

**Content for Chemistry**

**SC5.** Students will understand that the rate at which a chemical reaction occurs can be affected by changing concentration, temperature, or pressure and the addition of a catalyst.

- a. Demonstrate the effects of changing concentration, temperature, and pressure on chemical reactions.

**SC7.** Students will characterize the properties that describe solutions and the nature of acids and bases.

- a. Explain the process of dissolving in terms of solute/solvent interactions:
- b. Compare, contrast, and evaluate the nature of acids and bases:
  - pH

### **III. MATERIALS**

- Resource and references; websites - listed in section VI
- School yard with varied vegetation that can be picked: (from) trees, flowers, shrubs, weeds, and/or additional plant material as required by student generated questions: onion skins, head of red cabbage, tea bags, variety of wood shavings, etc... (< \$10 for misc. groceries if not already in your pantry)
- dish pans
- water source
- buckets
- pyrex© beakers
- mortar & pestles
- plastic knives
- forceps or tongs
- gloves
- pH paper
- thermometers
- triple beam balances
- bags to store samples
- clothesline/rack to dry fabric
- hot pot or hot plate to boil water
- scissors
- food processor or blender to finely chop plant material
- cheese cloth & string for make shift “tea bags”
- untreated wool for dyeing (\$2 to \$5)
- timers
- mordants: alum, cream of tartar, vinegar (< \$5)

### **IV. PREPARATION**

#### **A. Engaging Students - Introductory Question – The “Hook”**

This investigation will begin with me entering the classroom dressed, quite uncharacteristically in a very colorful Tie-dyed T-shirt or lab coat. This alone will automatically elicit a response from the students – both comments and questions. I'll ask them if they like my T-shirt. What they like about it? What do they notice about my T-shirt? Do they have a Tie-dyed T-shirt? Have they ever made a Tie-dyed T-shirt? What did they use to make it? I'm certain the response will be that they used RIT© Dye

to do this. Okay, but what if, in this economy we're currently experiencing, that the RIT© Dye company is in trouble. They have been laying off an awful lot of its workers and the company is now in serious financial trouble. What if the company folds? What happens to the Tie-dye Industry then? I'll allow time for my students to discuss this and lead them toward what people used long before RIT© Dye. We'll spend some time talking about the historical aspect of dyeing fibers – who did this, when, what did they use..... among other things.... plants. I'm certain that they will come to this conclusion on their own, afterall, many of them can still see the grass stains on the knees of their blue jeans!

I would like to then show them a few other items that have been colored with plant dyes, such as: wool used for knitted items or in weavings, basketry, etc... We can spend a bit of time talking about the people and cultures that created the items, the materials used to make and dye them and the location of the plants used.

I would then ask them if they had any questions that we could share and discuss. I've listed in the next section the expected student questions that might be generated, highlighting the ones I would prefer to steer the students toward.

## B. Questions

### **Expected or possible student questions:**

How do you dye fabric?

What is RIT Dye?

Have we always used RIT Dye?

What was used before RIT Dye?

What methods are used?

#### ***What materials are used?***

How has dyeing textiles changed throughout history?

What did they use generations ago to dye their textiles?

Were the methods or materials any different?

#### ***What are organic and synthetic dyes?***

How are they different?

How are synthetic dyes made?

#### ***Where are organic dyes found?***

#### ***What type of plants can be used?***

#### ***Can all parts of the plant be used to dye textiles?***

#### ***Do some plants or parts of those plants yield a better dye?***

#### ***Does the color of the plant/flower yield that same color dye/pigment?***

How do you get the color out - how do you extract the dye from the plant material? (shredding, cutting, grinding, boiling, soaking)

Is there a "best" way or does it depend on the materials being used?

How do you get different hues or intensity of color onto the fiber?

Why does some color stay and others don't?

Why isn't all color permanent? How can we make it permanent?

(Note: ***Bold/Italicized*** questions are those which I'd like to guide the students toward for the initial investigation. Other questions may be part of further extensions of this investigation that can be pursued later)

### C. Sample Hypotheses and Predictions:

**Hypothesis:** We believe that only the leaves of a plant or the petals of a flower will yield enough color to dye fiber because they have the most saturated color already and it will be the same color as the part of the plant.

**Prediction:** If only the color of the plant/flower is the color of the dye, then ground up leaves of sassafras will dye the fiber green.

If the color of the plant/flower is the color the dye, then the ground of petals of a daylily will dye the fiber orange.

If the color of the plant/flower is the color of the dye, then the ground up roots of a dandelion plant will not dye the fiber as the roots are white.

**Aha moment:** sassafras leaves yield a shade of orange; old daylily blooms yield shades of red to purple; and dandelion roots yield a brown color! (This could be very interesting indeed!)

## V. DESIGN AND IMPLEMENTATION OF THE INVESTIGATION

### A. Experimental Design

1. Group decides what they will study - make their observations, develop a hypothesis, make their predictions, etc...and design their investigation.
2. Collect plant samples from the schoolyard.
3. Prepare some of the wool with mordant - This step will be done prior to the investigation by the teacher and not discussed until the end of the investigation. This may lead to additional questions for further extensions regarding mordants.
4. Chop up samples to be used (leaves, stems, roots, petals, etc...) using any method the student groups decide is best suited to their investigation.
5. Quantify amount of sample to be used using balances and any other measurement devices as necessary – as dictated by the students' investigation.
6. Using small amount of hot water, steep material to extract color – allowing time to “steep” and concentrate color.
7. Place fiber into the color vat.
8. If time is a variable, take time measurements (example: a longer “steep” time in the color vat will yield a darker color...).

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9. Remove fiber from color vat and rinse with cool, clear water.
10. Blot to remove excess moisture with a non-dyed fabric or paper towel.
11. Hang fiber to dry.
12. Observer and record results.

## **B. Agenda**

**Day 1** - Begin with the introduction question to the class. Listen to their ideas and observations. Begin discussing historical component of dyes, other cultures, methods, etc... Ask students what they think about using plants. What plants can they use? Can they use all the parts of the plant (leaves, stem, roots, bark, etc...?) What would they like to investigate about that?

Divide them into groups and have them discuss their ideas and questions and observations together. Have the students start thinking about their hypothesis and prediction to formulate a plan for their investigation. Take them outside to the schoolyard to collect their samples.

**Day 2** – Ask them how one goes from the plant to a colored shirt. How do you extract the color components from the plant? What do they know about it already? What would they like to know? What way will they use? Before beginning the extraction phase – ask the students to take before and after pictures of the plant material, or make a video or drawings of them in their notebooks – with color if possible. Begin the extraction phase and the dye process. How should this be done? What is the best method? Cutting or tearing? Should they use big pieces or little pieces? How much should be used? Remind them to record this information in a data table in their notebooks.

Discuss mixtures with the students – homogeneous vs. heterogeneous mixtures. Ask what type of mixture we have during this extraction phase? Discuss solutions with them: solute and solvent. What is concentration? Does it have an effect on the dye process? How so? Is their solution acidic or basic? How could they test for that? Does pH matter in the dye process? Does temperature have any effect in the extraction or the dyeing process? How so? Remind them to record this type of data to a table in their lab notebook. At this point I may, as an aside, ask one group if they'd do a test for me using red cabbage – which changes color as pH is altered).

Have the students save some plant material for a chromatography experiment they'll do later. When the dye solutions are ready, have them place the fiber into the "dye pots" (whatever receptacle they used to steep and prepare their dye). Remind them about time – is it important for this? Do they need to time how long they keep their fibers in the pot? Record any additional data. Hang fabrics to dry. Show them a color yarn sample (punched out cards with dyed fibers displayed in some type of arrangement/organization – how could they organize or display their samples during their presentation to the class?)

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**Day 3** – Groups will look at their dry fiber samples and complete their observations and record them in their data tables. Each group will prepare a poster to present their investigation and conclusion to the rest of the class. The presentations will be given during the last part of the block. Individual Lab Reports will be turned in on Day 6. Discuss what they can do with their fiber samples – braided bracelets or bookmarks.

**Day 4** - Discuss color and chromatography. Groups will conduct a chromatography experiment on the remaining plant samples they've collected– focusing on those parts that yielded a different color than expected. What did the students observe? Is there any connection or relationship between the two investigations? This will invariably lead into a discussion of color and pigments – What are the primary pigments? How do our color printers work with only 3 colors in the cartridge? How do you get black? Have them record this and any additional thoughts or questions in their lab notebooks.

**Day 5** - Discuss color and the Electromagnetic Spectrum focusing on light waves (transverse waves), energy and photons, reflection, refraction, diffraction, frequency, wavelength. Where on the EM spectrum do we find visible light? What frequency range is that? Do they see any order or arrangement there? What does it remind them of? A rainbow - How do you get a rainbow? Discuss the separation of light through a prism. Discuss primary light colors. Are they different from the primary pigment colors? Have them write their questions and observations in their lab notebooks.

Conduct a Final Class Reflection for the investigation. What did they like or dislike about this investigation? What could be improved? What did they learn? Would the students like to do further investigations? Which ones? Why?

### **C. Sampling Sites**

I really need to get back home and do a good walk through of my school yard. I really don't know what we've got. I'll need to do some identification of plants and draw a better map. I'll need to guide my students to an area where there are suitable plants for this investigation. If I need to "supplement" the schoolyard samples, I will also plan on having a variety of other things to subtly suggest to a group if they'd try one of these things as well, "just to see" what happens. An example of those things would include: red cabbage (color will alter based on pH), onion skins of different colors (red onion skins dye a more brown/earth tone), etc...

### **D. Predictions**

Sample hypotheses and predictions were written in a previous section.

## E. Analysis and Communication

At the conclusion of this investigation each group will present their findings to the class as a poster presentation showing their dye samples.

## F. Grading

I have a rubric I use for the lab notebooks/reports. Their grade will/should include participation, presentation and an individual lab report. In addition, each group member will turn in their lab notebook for review/grading. Every person is responsible for writing down their observations, questions, hypothesis, prediction, materials list, procedure, data tables, analysis, conclusion, list of possible errors, and further extensions.

## VI. RESOURCES

1. List of plants and the colors they yield - the parts of the plants used to yield that color. <http://www.pioneerthinking.com/naturaldyes.html>
2. Short introduction to the Botany and Chemistry of Dyes, list of plants and basic procedures.  
<http://www.kidsgardening.com/Dig/DigDetail.taf?ID=943&Type=Art>
3. Chemistry Textbook references  
World of Chemistry – McDougal-Littel  
Chapter 1 – Chemistry, an Introduction  
Chapter 5 – Measurements and Calculations  
Chapter 15 – Solutions  
Chapter 16 – Acids and Bases  
Chapter 20 – Organic Chemistry  
Chapter 21 - Biochemistry
4. Physical Science Textbook references  
Physical Science – Glencoe  
Chapter 1 – Introduction to Science  
Chapter 8 – Solutions  
Chapter 9 – Acids, Bases and Salts  
Chapter 14 – Heat and Temperature  
Chapter 16 – Sound and Light
5. The Art and Craft of Natural dyeing, Traditional Recipes for Modern Use by J.N. Liles, University of Tennessee Press (Great Resource for the chemistry component, actual formulas for certain dye colors from specific plants; the chemistry of mordants)
6. Dye Plants and Dyeing by John and Margaret Cannon, Timber Press in Association with The Royal Botanic Gardens, Kew

7. **A Dyer's Garden, from plant to pot growing dyes for natural fibers** **Dyes from American Native Plants, a practical guide** by Rita Buchanan (How to get started planning a garden for natural dyes)

8. **Dyes from American Native Plants, a practical guide** by Lynne Richards & Ronald J. Tyrl (Great book with pictures and lists of the plant and plant parts with the color they render and what it looks like on different fibers and mordants)

## **VII. BUDGET**

I, or another teacher in my department will have most all the equipment – cost should be close to \$0 to less than \$20 as listed in Materials section above.

## **VIII. EXTENSIONS**

### **A. My own thoughts...**

1. Catalog the plants in our school yard with the color they produce.
2. Have students design their own tie dye or dyed design on a T-shirt or bandana using the plants from the school yard.
3. Have students copy a design common to a culture and recreate it.
4. Coordinate with other departments to “marry” this investigation with one they are currently doing. Example: History – studying the middle East – the students can investigate what the people in that region used to dye their textiles? What colors are predominant in their garments and rugs?
5. Is the color we get from these plants different when we use different fibers? Example: wool vs. cotton; muslin vs. silk; different papers or eggshells.
6. What other things besides plants can yield a dye? GA red clay or ground up minerals.
7. Are mordants always required?
8. What effect do different mordants have on different fibers or dyes?
9. What is the actual chemistry of the mordant-fiber-dye reaction in this process?

### **B. Those generated by the students after completing the initial investigation...**

## **IX. REFLECTIONS AND REVISIONS (THE GOOD, THE BAD, THE UGLY)**

This will be the place I'll record my thoughts and observations about how the investigation went. Was it successful? Did the students enjoy it? Did they get out of it what I had hoped? What were their responses? What were the problems? How can it be improved? Etc...