OIEE - School Yard Investigation Plan
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BETTER LIVING THROUGH CHEMISTRY: KEEPING IT CLEAN

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

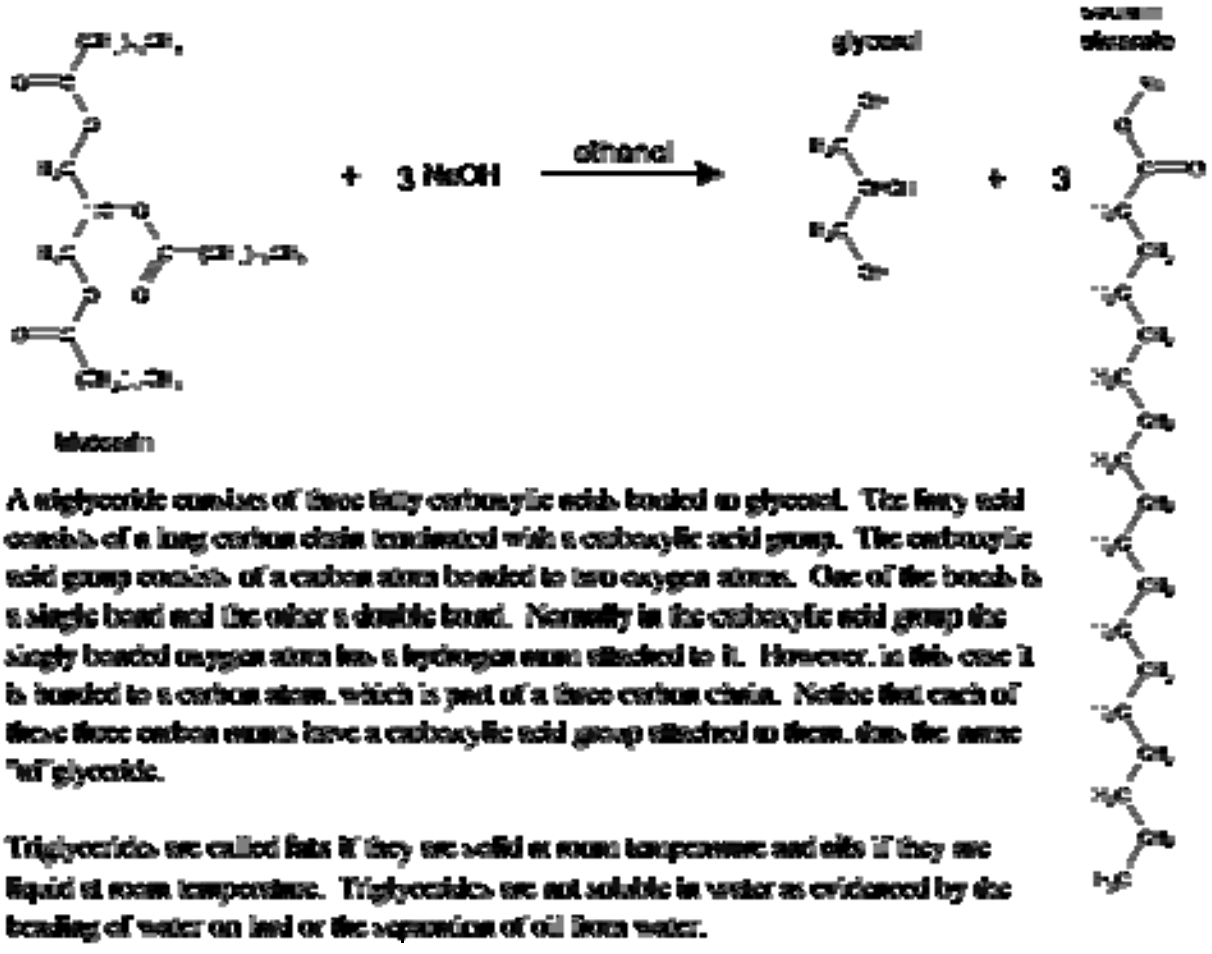
I. BACKGROUND

Many of my students think only of Chemistry as a difficult subject they must take in school and absolutely dread it. I hear them complain repeatedly, "If I'm not going to become a Chemical Engineer or Doctor, why do I have to take this class!?" I try to teach my students that chemistry is not just a class they have to take, but a daily experience that occurs all around them, every day. Each semester I notice how oblivious many students are to the chemical processes that occur around them - from the burning of gas in their cars to get them to school, to the breakdown of their food during lunch to provide fuel for their bodies, to the products they use daily for their own personal hygiene. As a result, I wanted to incorporate a bit more of our "daily life" into the classroom so the students might appreciate a bit more what chemistry has to offer. This investigation is the result.

I begin the unit - Chemical Reactions & Equations, by reviewing Physical and Chemical Properties and changes, then move on to, "How do you know a chemical reaction has occurred?" They learn that evidence of a chemical reaction can be: a color change, a new substance formed, heat production, gas emitted or flame. After the students learn how to identify when a reaction has occurred and what information is included in a chemical equation, they learn how to balance it and the types of reactions there are, in order to predict what the products will be. After introducing types of chemical reactions to the class, I show them a common household product, a bar of soap, and begin discussing what goes into it's production. It's the perfect tool for this unit and an investigation where the students can explore a reaction and make something tangible using their knowledge of Chemistry.

The focus of this Investigation is to explore this common household substance, which is the product of an Acid-Base Reaction. The products of an Acid-Base reaction are a salt (a soluable ionic compound) and water (which will evaporate as the saponification process proceeds), leaving behind a solid - the bar of soap. Refer to the following figure:

A triglyceride (fats or oils) reacts with NaOH (sodium hydroxide) to yield glycerol (an alcohol) and a salt (the soap - sodium stearate) - ethanol is occasionally used to keep the reaction at a lower temperature and will evaporate out during the reaction, I personally do not use ethanol or sodium chloride when making soap as other recipes indicate:



A triglyceride consists of three fatty carboxylic acids bonded to glycerol. The fatty acid consists of a long carbon chain terminated with a carboxylic acid group. The carboxylic acid group consists of a carbon atom bonded to two oxygen atoms. One of the bonds is a single bond and the other a double bond. Normally in the carboxylic acid group the singly bonded oxygen atom has a hydrogen atom attached to it. However, in this case it is bonded to a carbon atom, which is part of a three carbon chain. Notice that each of these three carbon atoms have a carboxylic acid group attached to them, thus the name "tri"glyceride.

Triglycerides are called fats if they are solid at room temperature and oils if they are liquid at room temperature. Triglycerides are not soluble in water as evidenced by the beading of water on lard or the separation of oil from water.

When triglycerides are reacted with sodium hydroxide, the bond between the oxygen atom of the carboxylic acid group and the carbon atom of the glycerol is broken. This

process is called **saponification**. The oxygen atom picks up the sodium atom from the sodium atom from the sodium hydroxide and make this end of the fatty acid chain soluble in water. This sodium salt of a fatty acid is the solid soap. The (OH^-) hydroxide ion attaches to the glycerol molecule. When all three fatty acids are removed, the reaction is complete.

The unique properties of soap lie in the fact that one end of the chain is water soluble (hydrophilic) and the other is not (hydrophobic). When using soap, a particle of grease or dirt is surrounded by soap molecules (forming a micelle). This allows the dirt particle to freely move around in the water and be washed away - thus leaving the area (hands or clothes) clean.

The fats and oils used in soap making are different fatty acids such as: Oleic and Linoleic Acid found in Olive Oil; and Caprylic, Capric and Myristic Acid found in Coconut Oils. Some of the soap characteristics produced by the different fatty acids are as follows:

Fatty Acid	Hard Bar	Cleansing	Fluffy Lather	Conditions	Stable Lather
Lauric	X	X	X		
Pamitic	X				X
Stearic	X				X
Ricinoleic			X	X	X
Oleic		X		X	
Linoleic		X		X	

(This chart is quite helpful when designing the features you wish to incorporate in your soap.)

If all the carbon bonds in the fatty acid chain are single bonds, it is called a saturated fatty acid. If any of the carbon bonds are double bonds, it is an unsaturated fatty acid. Unsaturated fats can be converted to saturated fats by adding hydrogen atoms at the locations of the double bonds. The amount of unsaturated fatty acids in the soap can affect the firmness of the soap.

Note: My focus with this SYIP is to try to incorporate Environmental Science as much as I can in each lesson I present to my students. My school yard is wooded and doesn't lend much to the gathering of herbs and such, for this lesson in particular, but many citizens in the community do have gardens and the city has a number of parks with gardens with a greater variety of vegetation. I'm hoping that what we lack in the way of various school yard plant materials can be found in the students' own backyards and in the community. I just want to get the students thinking about plants and the impact they can have. I'd like to get them to think and act a little "greener."

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.

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 Chemistry

SC2. Students will relate how the Law of Conservation of Matter is used to determine chemical composition in compounds and chemical reactions.

a. Identify and balance the following types of chemical equations:
- Synthesis
- Decomposition
- Single Replacement
- Double Replacement
- Combustion

b. Experimentally determine indicators of a chemical reaction specifically precipitation, gas evolution, water production, and changes in energy to the system.

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 and/or community with varied vegetation that can be picked, such as leaves, bark or blossoms from trees, flowers, shrubs, weeds, and/or additional plant material as required by student generated questions. For example: marigold leaves, mint leaves, aloe, chamomile and other herbs for their nutritive or colorant properties
- water source

- non-metal mixing bowls such as pyrex© beakers, measuring cups or bowls (readily available in a school lab setting)
- forceps, beaker tongs or “hot hands” to move hot glassware (readily available in a school lab setting)
- gloves
- protective aprons
- eye protection - goggles
- pH paper - optional
- thermometers
- balances: triple beam, electronic or kitchen scale are all acceptable (readily available in a school lab setting)
- heat source - hot plate (readily available in a school lab setting)
- food processor, blender or mortar & pestle - to finely chop plant material if necessary (in kitchen pantry or school lab setting)
- cheese cloth & string or coffee filters to make “tea bags” - optional, dependent upon student’s investigation
- fats and oils - Example: olive oil (16 oz approx. $8); lard (32 oz approx. $4); coconut oil (5 lbs - $13 Majestic Mountain Sage, http://www.thesage.com); Palm and/or Palm Kernel Oil (5 lbs. - $13 MMS); liquid soybean oil (16 oz - $4) or hydrogenated soybean oil (10 lbs - $21 from MMS) - many of these materials can be found in a kitchen pantry
- Sodium hydroxide (NaOH), solid/pellet form (2 lbs - $4 from http://www.camdengrey.com/essential-oils/Soap-Making-Supplies-Lye-Potash/ or chemical supply house (Fisher Scientific) - may already be available in your schools’ chemical store room
- stirring spoons - wooden spoons
- stick blender - optional
- add in materials such as honey, almonds, oatmeal, milk, coffee, coffee grounds, flax seed, seaweed, fragrance, spices, etc... - optional
- Petroleum jelly ($3) to “grease” the inside of the mold to prevent “sticking” of the soap
- suitable containers for soap molds: shoe boxes lined with garbage bags, PVC pipe, aluminum loaf pans or muffin tins, etc...
- use of computers to access websites to do research of ingredients, access the Lye Calculator in developing their soap recipe and to design their brochures, ad campaigns and reports - computer lab at the school if available, media center or home use
- projector - optional – suggested to show the students how to use the Lye Calculator found at http://www.thesage.com

IV. PREPARATION

Engaging The Students – The "Hook"

This investigation will begin with me entering the classroom with my hands and arms completely covered in dirt and marker dust - filthy! I'll have them begin their bellwork and continue working on the day's lesson helping students until someone suggests that I wash my hands; at which point I'll proceed to the sink and discover a number of different soaps there. Hmm... Which soap should I use? Does it matter?

This is how I anticipate the discussion would start - I'm hoping to draw them into a lively discussion about what they've already noticed about the soaps they've used and how they think they are made. This discussion, of course, is right in the middle of the unit on Chemical Reactions and Equations, after the introduction of tTypes of Reactions. I'd like to lead them into a consumer science investigation first: What makes a "good" or "desirable" bar of soap for you? Their initial challenge will be to design an investigation exploring the properties of soap and to determine what functions or properties they find suitable in a bar of soap. Sample Questions might be: Are big bubbles and how well a soap lathers characteristics of a good bar of soap? How do you measure how well it cleans? Do the bubbles or lather last a long time? How does it make your skin feel after using it? The student teams will need to narrow down what characteristics they feel a good bar soap should have and design an experiment to test them. They'll need to determine how many different soaps to test, who will test them, how to test them, establish an evaluation system, etc...

At the conclusion of the investigation they will present their findings to the class so we can discuss the properties of soap they liked, for example: large bubbles/good lather, nice smell, how their skin felt after using, any mildly abrasive properties of an added substance they enjoyed, the color, etc... This information will lead into what materials give these properties? What are the ingredients for soap? Do the ingredients really make a difference? How can you "design" a soap for a specific purpose? What materials are available for soap making? How do you get them into a soap recipe?

I will introduce to them how soap is made and the products used to manufacture a bar soap. As I plan to have already introduced the class to the types of chemical reactions, I will refer to those notes at this time - that the production of soap is an acid - base reaction and the products are a salt and water. We'll talk specifically about the saponification process and the formation of glycerin and what it lends to a bar of soap. My final question will be to ask them where one can find these ingredients? All but the sodium hydroxide can come from plant materials.

I like to add some cross-curricular connections as well: History - where, when soap was first introduced; math - saponification values for the fats and oils to determine amount of lye used, percent mass composition; psychology - a person's senses: smell, touch, memory, etc...; art - design of packaging and developing an ad campaign; kinesthetic - actually having to create a product and perform an action during this investigation.

At the conclusion of their consumer product investigation, the information they gathered will be the basis for their next challenge and investigation. They are to form a Company, in order to develop, manufacture, and market a product - their product being a bar of SOAP. They will be required to choose 1-3 characteristics for their bar of soap that some plant material is responsible for contributing as an add-in ingredient they can gather from the school yard and/or community gardens (with permission). They must submit a completed bar of soap that has been packaged, along with a brochure describing the features of their product and a lab report outlining the manufacturing process of their product and present it to the class.

Questions

Expected or possible student questions:

Is one soap better than the other? How do you know?
What makes a soap good or bad?
Is it purely a personal choice?
Are all soaps equally effective at cleaning?
Is cleaning the only thing that matters in a bar of soap?
What does it matter what soap is made out of?
Are all vegetable materials suitable for soap making?
Why or why not?
What properties are given to a soap by this plant material?
What type of reaction is this?
Can plant material or other natural substances be used to color the soap?
Is one soap really better for my skin than another?
Can a soap really prevent a skin condition?
What other uses are there for it besides washing your hands?

(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)

Sample Hypotheses and Predictions:

Hypothesis: We believe that a good bar of soap will stay firm after many uses, leave the skin soft and have a long lasting, rich lather.

Prediction: If after 10 uses of this soap, the skin is not red, dry or flaky, then this soap has a desirable characteristic (a good level of emollients) and is effective.

If the soaps' lather and bubbles stay firm, full and consistent for more than 5 minutes, then the soap has a desirable characteristic and is effective.

If the soap is left wet after use without draining or drying and after 1 hour if it has not melted or become unusable in bar form, then it is considered a good, firm bar with a desirable characteristic and is effective.

Thinking moment: What ingredients give these properties? The students should research this when developing the recipe for their own soap and include this information in their report at the conclusion of the investigation.

V. DESIGN AND IMPLEMENTATION OF THE INVESTIGATION

Experimental Design

- Group decides what characteristics they will study - make their observations, ask their question, develop a hypothesis, make their predictions, etc…and design their investigation.
- Collect testing samples - the different bars of soap. I will provide some and students may incorporate their own types/brands from home.
- The students will conduct their investigation and draw their conclusions based upon their data.
- This data will then be used as the basis for designing their own bar of soap. The website http://thesage.com - has a very helpful Lye Calculator the students can use for help with their recipes. Set the total weight of soap to be made (I suggest between 200 - 600 g depending on the amount of materials available and number of students).
- Soap Making Procedure:
- while wearing safety goggles and gloves, combine the solid NaOH to the liquid - add slowly and stir well. Set aside to cool (100°F to 125°F). This should be done in a fume hood or outside the classroom as you stand upwind.

- weigh out and combine the fats and oils into a non-metal, non-plastic pan or beaker. Heat gently until all fats and oils are melted. Allow the temperature to cool (100°F to 125°F).
- Add the lye solution to the melted oils slowly - more like a drizzle. Be careful not to splash while combining the mixtures. Continue to stir until the mixture reaches **trace.** Tracing looks like a slightly thickened custard or pudding. It will support a drop or the stir marks for a few seconds. If stirring by hand, it may take from 30 - 45 minutes to reach trace, a helpful tool is a stick blender - reaching trace takes only 5 - 10 minutes for most batches. If using a stick blender, be careful not to splash or lift the assembly too high up to cause the mixture to spray. Rinse and clean thoroughly after use.
- If tracing takes more than 15 minutes, stir for the first 15 minutes, then for only 5 minutes at 15 minute intervals. Once trace occurs....
- At trace is when you can add additional ingredients - colorant, honey, oatmeal, grated citrus, etc... Stir the add-ins until well mixed throughout.
- Pour raw soap into prepared mold. After 24 - 48 hours the soap can be turned out of the mold. A helpful trick to get the soap out cleanly is to freeze it for a few hours. It usually pops right out. If the soap is still a bit soft, allow it to cure and dry a few more days to firm up. The saponification process may not be finished.
- A white powder may be noticed on the surface of the bars - this is soda ash, a product of the reaction. It can be wiped off or will readily wash off at first use.

Agenda

Day 1 - Begin with the “Hook” and discuss what makes an effective or “good” bar of soap. Challenge the students to look at 1-3 desirable characteristics and how they would measure/evaluate them. Have the students divide into groups and begin their investigation for part I. They should be discussing and deciding on the question - or characteristics they wish to study, develop their hypothesis and make their prediction. They’ll need to outline their experimental design, decide what samples to test, and gather their materials. NOTE: *You may want to allow a few days to complete this investigation. If so, you can introduce this at the start of the unit and begin Part II (production of the soap) after the introduction of Types of Chemical Reactions.*

Days 2 to 3 – Groups will present their findings to the class and as a class we will discuss what attributes are desirable and why? This should lead into questions of what ingredients give these properties to soap. We will then present information on a few ingredients commonly used to make soap and what they contribute to the end product due to their unique chemical properties. The students should see that all these

ingredients come from plant material. **Note:** soap can be made using lard or beef tallow but for this investigation I am choosing to focus on plant material only.

Ask them how one goes from the plant to a usable bar of soap. How do you use this plant material or prepare it for the soap? What do they know about it already? What would they like to know? In what way will they use it? Why?

Discuss with the students about reaction rates and factors affecting them. Specifically refer to temperature of the reactants and exothermic reactions. The soap making reaction needs to stay within a specific temperature range and will produce heat. At this time I will assign them their next challenge - making a bar of soap and then assign the students into their "companies." Outline the procedure for this assignment with them. Show them the helpful website they may utilize to develop their recipe. As a company they should discuss what type of product they'd like to produce. You may want to allow access to computers with Internet to do research on their ingredients and develop a suitable recipe. You should look over their recipe to ensure it is acceptable. They will need to gather their plant materials and other ingredients not provided by the instructor.

Days 4 to 5 – Production Day - depending on the size of your class and the size and preparedness of each company - production may take 2 days. If using the Lye Calculator from the Majestic Mountain Sage website, the students can print a copy of their recipe with complete instructions. **Soap making instructions are outlined in the Experimental Design Section listed above.**

Day 5 or last day - This should be Presentation Day - each Company will present their packaged soap and their Ad Campaign to the class.

Sampling Sites

My school yard is heavily wooded on its perimeter, mostly pine with white and live oak trees. This wooded perimeter is located quite a distance from my classroom and may cause time issues and hav an inadequate variety of plant material necessary for this lesson. Therefore, I am asking students to be creative, using not only our school yard, but their own yards and the community gardens available in the city parks, or even their own kitchen pantries. I will continue to emphasize the role of plants and the many uses for them.

Predictions

Sample hypotheses and predictions were written in a previous section.

Analysis and Communication

At the conclusion of the first consumer investigation, the groups will present their findings to the class as a poster presentation showing their data. For the second investigation & challenge, each group will present the final product as part of an ad campaign such as a radio announcement, magazine ad, commercial, etc...

Grading

I use a simple rubric to grade each of the elements I wish them to turn in. You may develop your own based on this depending on what you'd like to have the students focus on. I plan to refine this rubric each time I do the lesson as I gain more experience with it. The rubric is included at the end of this plan.

VI. RESOURCES

1. Chemistry Textbook references

World of Chemistry – McDougal-Littel
Chapter 1 – Chemistry, an Introduction
Chapter 5 – Measurements and Calculations
Chapter 7 - Chemical Reactions
Chapter 8 - Reactions in Aqueous Solutions
Chapter 15 – Solutions
Chapter 16 – Acids and Bases
Chapter 20 – Organic Chemistry
Chapter 21 - Biochemistry

2. Bramson, A. (1975). *Soap - Making it, Enjoying it*. New York: Workman Publishing Company, Inc..
3. Makela, C. (1997). Milk-based soaps - Making natural, skin-nourishing soap. Pownal, Vermont: Storey Communications.
4. Browning, M. (1999). Natural Soapmaking. New York, NY: Sterling Publishing Company, Inc..
5. Cavitch, S. (1995). The Natural Soap Book - Making herbal and vegetable-based soaps.
6. www.thesage.com - Majestic Mountain Sage - Fabulous Website with recipes, instructions, product ordering information, equipment and lye and fragrance calculators
7. http://www.camdengrey.com/essential-oils/Soap-Making-Supplies-Lye-Potash/ - ordering soap making supplies

VII. BUDGET

I, or other teachers in my department, will have most all the equipment and supplies needed – the cost could range from $0 to $60 if you must purchase all the fats and oils as listed in Materials section above.

VIII. EXTENSIONS

My own thoughts...

1. Research the chemical equations for each oil used in a recipe.
2. What else can we make in class using our knowledge of chemistry?
   a. lip balms and other personal care products…
3. Explore a basic soap recipe and vary the amounts of each ingredient to record what property has been affected.
4. Explore different types of reactions the students can demonstrate in class with the production of some useful product.

Those generated by the students after completing the initial investigation...

1.
2.
Etc…

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...

SOAP MAKING PROJECT - GRADING RUBRIC

CRITERIA	3 points	2 points	1 points	0
Has made and turned in 1 bar of soap	-dry, finished, hard bar of soap			- no soap turned in
Packaging	-packaging present -pleasant, neatly done, -looks professional	- packaging present - neatly done	- packaging present	- no packaging present or very poorly or sloppily done
Brochure/product flyer	-include complete description of product & ingredients -company information -graphics -professional look	-description of product and ingredients - company information - some graphics included	- description of products are vague and incomplete - company information is vague or incomplete	- no brochure included or very poorly done
Ad Campaign	- presentation well done - ad campaign effective & informative - good use of materials/tech - creative	-presentation done - ad campaign informative and/or effective	- presentation done - ad campaign somewhat informative	- no presentation done
Report	-materials & procedure -type of rxtn and equation included -typed	- materials & procedure - type of rxn, equation included	-materials & procedure	-report missing or very poorly done