WISELearn Resources

Career Academy Teacher Externship Program

Title: The Chemistry of Paper-making

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Externship Business: BPM Inc. A Specialty Paper Mill

Overview / Description:

This series of activities in this unit provides background knowledge for students to ultimately understand the science of papermaking at a molecular level. These activities will include learning about carbohydrates, building models to demonstrate how polysaccharides form in condensation reactions, watching videos describing the general steps in the papermaking process, and learning about how additives to pulp can enhance the overall strength of a finished paper product. This knowledge will be used to provide the tools for students to explore papermaking in an inquiry-based format. Upon demonstration of the basics of making handmade paper with a papermaking kit, students will be challenged to change variables to determine which set of parameters results in the highest quality paper. This will truly be engineering design, but at the molecular level.

Subject(s):

Chemistry, Biology

Grade Level(s):

Grades 11-12

Learning goals/objectives:

After completing this activity, students should be able to:

- Distinguish between monosaccharides, disaccharides, and polysaccharides
- Model a condensation reaction when saccharides form glycosidic linkages
- Illustrate how structure is related to function for common polysaccharides (including starch, glycogen, and cellulose).
- Describe the role of additives in the final properties of paper
- Manipulate experimental variables to engineer a most ideal process for producing a high-quality sample of handmade paper.
- Compare handmade paper techniques to industrial methods.
- Communicate scientific reasoning that explains the properties of a final sample of paper

Workplace Readiness Skill:

- ✓ Social Skills
- ✓ Teamwork
- ❏ Attitude and Initiative
- ❏ Professionalism
- ✓ Critical Thinking
- ❏ Media Etiquette
- ✓ Planning and Organization
- ✓ Communication

Type of Activity:

- ✓ Individual
- ✓ Small Group
- ✓ Whole Class

Teaching Strategies:

- ✓ Discussion
- ✓ Partner/Team Work
- ✓ Use of Technology
- ✓ Simulation

Content Standards

Wisconsin Standards for Science

Physical Science - Matter and its Interactions

HS-PS1-3: Plan and conduct an investigation to gather evidence to compare the structure of substances at the bulk scale to infer the strength of electrical forces between particles.

Physical Science - Motion and Stability: Forces and Interactions

HS-PS2-6: Communicate scientific and technical information about why the molecular-level structure is important in the functioning of designed materials.*

Engineering, Technology and Application of Science - Engineering Design

HS-ETS1-2: Design a solution to a complex real-world problem by breaking it down into smaller, more manageable problems that can be solved through engineering.

Model Academic Standards for School Counseling

Academic Development Domain

Content Standard C: Students will understand the relationship of academics to the world of work, and to life at home and in the community.

- Core Performance Standard 1: Understand how to relate school to life experiences

Length of Time and length of class periods: 10-14 days (or more); see suggesting breakdown below. A class period is estimated at 45 minutes.

Materials List:

- Pulp sheets (may be obtained from a local paper mill willing to donate)

- If pulp sheets are not available, other household papers can be used (such as toilet paper, paper towel, newspapers, or any recycled paper can be used).
- If students don't build their own, kits can be built ahead of time using any standard paper-making kit design found online. Kits can can also be purchased in packages similar to this Flinn Paper-making Student Laboratory Kit
- Paper strengthening additives such as starch and/or guar gum
- Blenders and irons
- Shopvac vacuum cleaner
- Molecule building kits such as this kit from the University Chemistry Co.
- Student access to computers for research
- Individual student whiteboards and dry-erase markers for team planning sketches
- Rubric for paper-making assignment

Directions (Step-by-Step):

- Introduction to Carbohydrates (1-2 class periods)
    - Discuss monosaccharides, disaccharides and polysaccharides with examples. Pay attention to the condensation reactions that occur when disaccharides and polysaccharides form. This video summarizes these topics: Carbohydrates - The Basics amylose, starch, cellulose (time-5:48)
    - Compare alpha and beta glucose molecular structures. If model kits are available, have students build each and identify the #1 and #4 carbon atoms in each molecule.
    - Combine two glucose molecules into a disaccharide to demonstrate the glycosidic linkage and removal of a water molecule in this condensation reaction.
    - Compare and contrast amylose (starch) molecules, glycogen molecules, and cellulose molecules. Pay particular attention to the alpha-1,4 glycosidic linkages in starch, the alpha-1,6 glycosidic branches in glycogen (in addition to alpha-1,4 linkages), and the beta-1,4 glycosidic linkages in cellulose and how structure affects the overall molecular structure.
    - Compare and contrast the physical properties of starch, glycogen, and cellulose. Make connections between molecular structure and the role these molecules play in natural systems.
- Introduction to Paper-Making (1-2 Class Periods)
    - Students watch video which introduces the cellulose molecule, discusses the basics of turning wood chips into pulp, and includes a discussion on other uses of cellulose currently and potential uses in the future. How is paper made? Chemistry Calendar, April: Industry (time - 5:18)
    - Students watch The Paper Making Process (time-13:21) (or other similar video demonstrating the basic steps in the paper-making process). Pay particular attention to the water/pulp slurry being added to the mill felt, the compressing and vacuum action used to remove excess water from the paper, and the drying process. These steps will need to be replicated in an ultimate engineering design paper-making activity.
    - Discuss examples of additives that can change the overall paper properties. Since students will not really be able to alter the paper after drying, if additives are

experimented with to strengthen paper, they will have to be added to the pulp. To provide ideas for experimenting, show this video: Wet End Chemistry - Functional Papermaking Additives (time-1:46)

- Student Paper-making Engineering Design Challenge: Create a strong, smooth, aesthetically pleasing piece of paper using handmade paper-making techniques. (Note: the size can be specified according to a kit you have built or purchased or having student choice of the size could be part of student engineering design)
    - (1 class period) Students individually conduct online research for handmade paper-making projects to become well-versed in the steps involved and document initial ideas in a journal.
        - Things for students to think about: What are potential sources of the raw materials for this project? What materials might have to be brought from home or purchased? Do any resources support using additives for structural or aesthetic reasons? What tools might be needed?
    - (1 Class Period) Break students up into sets of partners or teams of three people. Allow time for students to discuss ideas and develop a tentative plan for the project. In their journals, they should sketch the plan and also develop a list of materials that will need to be purchased or brought from home.
        - If you have kits, show what is available and allow them to choose those materials if they like. Also, place blenders, irons, and a shop vac in clear sight to serve as suggestions for the engineering design process.
    - (4-5 Class Periods) Provide time for students to experiment with their paper-making design. Instruct them to document all progress in their journals, including changes or modifications made and the results.
        - The following is a list of suggestions students may experiment with. Students will likely develop these on their own or may need hints or prompting to spark ideas. The list is not inclusive, and it is likely they will be able to expand on it drastically.
            - Trying different sources of raw materials to create the pulp
            - Determining an ideal amount of pulp to use for best results
            - Experimenting with blend time to see if that affects the paper properties
            - Investigating how using additives and/or adjusting the amount of additives (such as starch or guar gum) affect the finished product
            - Exploring different pressing and drying techniques such as using the vacuum, pressing between cloth, or using an iron
            - Bleaching techniques and washing to produce a brighter final product

Wrap-Up:

- Students should display their final product and communicate a set of instructions for that final product.
- As a class, comparisons should be made between final samples, and properties such as strength, smoothness, and visual appeal should be discussed. As a class, create sound scientific explanations that support the quality of the final product. Encourage making

connections back to the molecular structures and how the orientation/interactions between cellulose molecules may have changed with each process.
- Students should create a final communication tool that ties the science of paper-making into the procedures they used. They should make comparisons between methods used and industrial paper-making. Ideas for this final communication include a poster, slide show, video, or 3-dimensional display modeling the process.

Formative/Summative Assessment:

- Formative assessment during hands-on model building and paper making activities include teacher observation and conferencing with groups
- Summative Assessment:
    - Teacher-created assessment to measure knowledge gained regarding the chemistry concepts involved in this activity
    - Rubric for paper-making assignment

Extension Activities for Differentiation:

- Obtain wood pulp and wood fibers from several different types of woods. Investigate under a microscope to make comparisons between the various raw wood fibers and pulp. It would be particularly interesting to see pulp from a 100% recycled paper source compared to virgin pulp.
- If access to a local paper mill lab is available, send samples of student paper to be tested for opacity, smoothness, thickness, and tensile strength. Compare results from each student paper and have students speculate how group paper design may have contributed to these properties.
- Students could design a poster of how the paper-making process they developed can be used as a model for actual paper-making on an industrial scale.

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