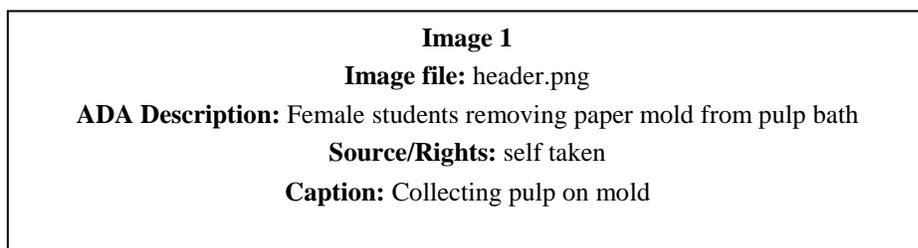


Blank Activity Template

Yellow highlight = required component

Subject Area(s) AP Biology
Associated Unit Plants
Associated Lesson Paper
Activity Title Paper Production from Pesky Plants

Header



Grade Level __ (6 - 12)

Activity Dependency

Time Required 45 min for molding, hydrolysis of lignin requires overnight preparation

Group Size 3 – 4 students

Expendable Cost per Group can be \$0 if sodium hydroxide is readily available, deckle/mold is home made, and pulp is made from freely available source (school grounds). Cost is highly variable depending on the sophistication of tools used.

Summary

Students will produce sheets of paper from plant material to demonstrate how natural products are converted into extremely useful items. Plant material is readily available in the form of undesirable plants either on school grounds or at home. This material needs to be collected and “beaten to a pulp”. The pulp is heated overnight in a basic solution of sodium hydroxide to hydrolyze the lignin, which helps separate the cellulose fibers. The fibers are then rinsed and further macerated in a blender. This pulp is then suspended in a large bin where a wire screen is used to collect a thin sheet of pulp. This layer is transferred to a felt (or denim) sheet, which can be stacked into a “post”. The post is pressed to remove as much water as possible and the wet paper sheets can be transferred to the classroom windows for drying.

Engineering Connection

Paper production offers an excellent means of allowing students to experience the fundamental steps used in manufacturing while the products are so common and widespread that students can comprehend the advantages of mass production. Students will be able to experience hands-on engineering concepts such as optimization (best water/pulp ratio) and learn the benefits of economy of scale.

Engineering Category = #1

Choose the category that best describes this activity's amount/depth of engineering content:

1. Engineering analysis or partial design

Keywords

Plants, cellulose, paper, biology

Educational Standards

Science: Texas, science, 2009, The Texas Essential Knowledge and Skills, Chapter 112

1B demonstrate an understanding of the use and conservation of resources and the proper disposal or recycling of materials

3D evaluate the impact of scientific research on society and the environment

Pre-Requisite Knowledge

Learning Objectives

After this activity, students should be able to:

- Describe how cellulose is used structurally by plants and as the raw material for paper
- Understand the benefits of engineering and mass production for everyday products
- Describe the importance of paper in the dissemination of information.

Materials List

Each group needs:

- 1 large bin to hold water/pulp mixture
- Enough pulp to make several sheets of paper (1 for each member is preferable)
- 1 Paper mold and deckle
- 1 Couching mold
- Enough felts/denim pieces for each piece of paper

Introduction / Motivation

Try to imagine your life without paper. Not just in school where all your books, worksheets, notes, and posters are made with paper, but also at home where you have tissues, mail, paper towels and paper plates. Would we even be as technologically advanced today if scientists and engineers didn't have scraps of paper around to do "back-of-the-envelope" calculations? Or tried to do their calculus homework on stone tablets? Probably not. Paper has given us the means to communicate ideas quickly, conveniently, and cheaply for hundreds of years. In the East Asian countries of China, Japan, Vietnam and Korea, everything from paper toys to paper clothes has been used for almost two thousand years.

Even though everything seems to be going digital these days, paper still has a strong place in our daily lives. One of the most interesting things about it is that the fundamental process of manufacturing paper hasn't changed since its invention in ancient China. Today, we can experience how simple it is to make a sheet of paper, and learn to appreciate how hard it is to make a good sheet of paper.

Vocabulary / Definitions

Word	Definition
Paper	Thin writing surface produced by the pulp of processed plant matter, mostly consisting of cellulose.
Cellulose	A structural polysaccharide of cell walls, consisting of glucose monomers joined by β -1, 4-glycosidic linkages. (<u>Biology</u> , 3 rd edition, Neil Campbell)
Economy of Scales	The decreasing of cost per unit produced with increased production volume
Couching	The act of transferring a sheet of pulp from the mold to a temporary fabric for pressing.

Procedure

Background

This lesson is contained within the unit plant physiology, after the students have learned basic structures and functions of plants. It enables students to gain hands-on experience of manufacturing of a useful product that very closely relates to the engineered processes used in industry.

Before the Activity

- The pulp used in this lab can be obtained two ways: 1) by blending scrap paper in water or 2) directly from woody plants. The second method is preferred as the purpose is to demonstrate useful products from natural materials, however, if not enough pulp is initially prepared, then scrap paper can be used to make up for the difference.
- To prepare cellulose, first plants must be gathered. Any plants will work, but those with more cellulose will be more efficient. Collect the plants and macerate them with a wooden or rubber mallet to preemptively separate fibers.

Figure 1

Image file: maceration.png

ADA Description: Beaten plant material is piled on a concrete slab. A rubber mallet, small hand shears and a flat blade lie next to the pile.

Source/Rights: Taken by Self

Caption: Preliminary maceration.

The flat blade was useful in collecting the plant material that had accumulated on the maceration surface. The shears are used to cut the beaten material into ~1 inch sections. Deposit this material into a stainless steel stock pot.

- In order to facilitate further maceration, the lignin is removed. The lignin can be hydrolyzed using a basic solution of 22 g/L sodium hydroxide. This process is speeded up if left to simmer overnight. The solution will start out with a light color (“white liquor”) and slowly turn black (“black liquor”). It may even start to smell fairly sweet. After cooking the solution, rinse the material with fresh water. Wearing rubber gloves, use an old shirt (for convenience and efficiency) over the brim of the pot and pour into the sink (since NaOH is used as drain cleaner). It is imperative to filter the water (shirt) before going into the drain for 2 reasons: 1) the small bits of pulp will quickly clog the drain and 2) the small bits of pulp are the best for making paper. Check the pH of your material occasionally to see when it is safe to handle without gloves.
- After the plant material is cooked and washed, it is time for the final maceration. Place a 50/50 mixture of plant material and water in a blender and use the pulse feature until you have a milkshake consistency. If you are using scrap paper, this is the step you start at. Tear strips of paper and combine

it with water to blend. After you have produced the pulp, you can add colorings, fragrances, etc. if so desired.

- The pulp is now ready for the classroom, however it would be good to prepare the mold and deckle. The mold is merely a surface that water can pass through, so if time is an issue, then a piece of wire mesh/screen or loosely knitted fabric can be used. Thick, boxy picture frames with screen mesh stretched over one side work well and you can use one for the mold and one for the deckle. The deckle is essentially a mold without a screen that keeps the water from flowing over the sides.
- In order to sufficiently transfer the freshly made pulp sheets, couching (coo-CHING) is required. Felts work best but denim can also be used. Make a couching mold by folding one felt into quarters, then on top of that place a felt folded into thirds, then in half then a full felt sheet. This way, the paper mold can be rocked over the couching mold and the paper will stick to the felt.

Figure 2

Image file: tools.png

ADA Description: A plastic bin filled with water and pulp mixture sits on a lab table with the deckle and mold on top. Next to the bin lies the lid with the couching mold on top. On the top layer of the couching mold is a sheet of pulp.

Source/Rights: Taken by Self

Caption: Papermaking setup

With the Students

1. Although there are no hazards for the students, we asked them to wear aprons and goggles for reinforcing good laboratory practices. Students will divide into groups and begin forming sheets from the pulp by submerging the mold and deckle into the pulp mixture and slowly bringing it up out of the bin. Pulp from undesirable sheets can be put back in the bin, as they are not degraded in any way. Also, students should mix the pulp by hand before each dip since the pulp settles to the bottom.

Figure 3

Image file: molding.png

ADA Description: A student is lifting the deckle and mold out of the pulp mixture to form a sheet of paper. A completed sheet lies on a strip of denim off to the side.

Source/Rights: Taken by Self

Caption: Students forming sheets of paper

Figure 4

Image file: couching.png

ADA Description: A student prepares to transfer the sheet of molded pulp to a moistened piece of denim on the couching mold.

Source/Rights: Taken by Self

Caption: Couching

2. Couching requires significantly more patience and practice than forming an even layer of pulp. Make sure the felts/denim are moistened. On denim, I've found it useful to lay the entire paper mold on top of the couching mold and rub the screen with my fingers as I slowly lift the paper mold up starting at one end of the mold. Again, pulp from mistakes can be put back in the bin and reused. Felts/denim with acceptable sheets of paper will be stacked into a "post" and need to be pressed to get as much water out as possible. We simply used the floor, a board on top of the post, and asked students to stand on top while others kept the mess at bay with towels. Sheets are damaged due to the uneven pressing, but are still usable. More sophisticated presses can be built (possibly as an engineering assignment for each group).
3. The paper sheets can be left on the felts to dry or transferred to a window. We transferred ours to a classroom window and they dried in ~1-6 days. The advantage of the window is you have at least one very flat face. The disadvantage is that if you do not get most of the water out and if the layer is thin, it is very difficult to transfer the paper without damaging it.

Figure 5

Image file: paper.png

ADA Description: Sheets of freshly pressed paper are stuck to the classroom window to dry.

Source/Rights: Taken by Self

Caption: Paper sheets drying on the window.

Attachments

Paper Lesson

Safety Issues

Troubleshooting Tips

Investigating Questions

Assessment

Pre-Activity Assessment

Descriptive Title: ___?

Activity Embedded Assessment

Descriptive Title: ___?

Post-Activity Assessment

Descriptive Title: Papermaking Quiz

Activity Extensions

Activity Scaling

- For lower grades, ___?
- For upper grades, ___?

Additional Multimedia Support

References

Inspiration and guidance in this activity were obtained from Caveman Chemistry, Kevin M. Dunn, Universal Publishers, 2003

Other

Redirect URL

Contributors

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Supporting Program

National Science Foundation GK-12 program, University of Houston, Department of Civil and Environmental Engineering

Classroom Testing Information

This activity was demonstrated at North Shore Senior High School, Houston TX, on April 19th 2013.