



## STEM Activities in the Clothing and Textiles Project Area



# Clothing and Textiles Project Area STEM Activities

Click on each activity number below to be taken to where it appears in the document.

<b>1-2 years</b>	
	Activity 1: Learning About Fabrics: Fabric Weave and Knit Structures
	Activity 2: Identifying Dyeing Process for Clothes
	Activity 11: Know Your Sewing Machine and How It Works
<b>3-5 years</b>	
	Activity 3: Thermal Quality of Fabric
	Activity 4: Protective Function of Fabric
	Activity 5: How Designs Are Made on Fabric
	Activity 6: How Fabric Is Made from Natural Sources
	Activity 10: Smart Apparel Products that Meet the Needs and Desires Today's and Tomorrow's Consumers
	Activity 12: The Nitty Gritty of Stains
	Activity 13: What's in that Detergent?
	Activity 14: To Make Or to Buy Your Clothes?
<b>6-9 years</b>	
	Activity 7: How Manufactured Fibers/Fabrics Are Made
	Activity 8: Fabrics Made with Nontraditional Natural Sources
	Activity 9: The Science Behind Fabric Finishes

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## 4-H CLOTHING AND TEXTILES PROJECT STEM LESSONS AND ACTIVITIES

STEM LESSON	LESSON AND HANDS-ON ACTIVITY DESCRIPTION	SUPPORTING MATERIALS NEEDED FOR HANDS-ON ACTIVITIES (Mobile Learning Kit With Items Listed Below Available for Lessons 1-9 at UT Extension Regional Offices)
<p><b>LESSON 1</b> Identify the difference in <b>woven and knit</b> fabric (<i>LEVEL Beginning</i>)</p>	<p>Lesson identifying various woven and knit fabrics and their qualities with crossword puzzle.</p> <p><b>Hands-on Activities:</b></p> <ol style="list-style-type: none"> <li>1. Group stretch comparing woven to knit fabric.</li> <li>2. Measuring the stretch of woven and knit fabric.</li> <li>3. Inspecting fabrics with magnifying glasses identifying weave and knit structures.</li> </ol>	<ol style="list-style-type: none"> <li>1. Two pieces of fabric (1 woven, 1 knit) 5 yds each sewn together.</li> <li>2. Fabric samples to use when teaching weaves and knit structures.</li> <li>3. Fabric weave and knit samples for identification.</li> <li>4. Tape measure and two pieces of fabric to measure (one woven and one knit).</li> <li>5. Magnifying glasses for weave and knit identification.</li> </ol>
<p><b>LESSON 2</b> Identify the <b>dyeing process</b> for various fabric types (<i>LEVEL Beginning</i>)</p>	<p>Lesson (1) basic dyeing processes and (2) tie-dyeing techniques.</p> <p><b>Hands-on Activities:</b></p> <ol style="list-style-type: none"> <li>1. Identifying fabric and yarns as fiber, yarn or fabric dyed.</li> <li>2. Examining samples of fabrics dyed using tea and blackberries.</li> <li>3. Examining various samples of tie-dyeing.</li> <li>4. Tie-dyeing activity (at home or project group) (supplies for hands-on activity to be furnished by leader; 4-H'er will bring T-shirt).</li> </ol>	<ol style="list-style-type: none"> <li>1. Samples of various tie-dye techniques.</li> <li>2. Supplies for tie-dyeing (rubber bands, rubber gloves, marbles) (need to supply dyes, T-shirt and other supplies needed for tie-dyeing).</li> </ol>
<p><b>LESSON 3</b> Compare <b>thermal function</b> of various fabrics for warmth (<i>LEVEL Intermediate</i>)</p>	<p>Lesson explaining thermal function of various fabrics.</p> <p><b>Hands-on Activity:</b> (Project group) testing various fabric types for thermal qualities.</p>	<ol style="list-style-type: none"> <li>1. 3 yards of fleece fabric.</li> <li>2. 3 yards of jersey knit fabric.</li> <li>3. 3 yards of top weight (shirt) fabric.</li> <li>4. Infrared Laser Temperature Gun.</li> <li>5. Magnifying glass to use to examine fabric.</li> </ol>
<p><b>LESSON 4</b> Compare <b>protective function</b> of various fabrics (<i>LEVEL Intermediate</i>)</p>	<p>Activity sheet with information and video links.</p> <p><b>Hands-on Activity:</b> (Project group) examining fabric swatches with protective functions and carry out experiments (nylon test water repellency sprits then pour; flame retardant burn).</p>	<ol style="list-style-type: none"> <li>1. Samples of fabric that protects.</li> <li>2. Samples of wetsuit fabric to use for experiments.</li> <li>3. Samples of ripstop nylon fabric to use for experiments.</li> <li>4. Samples of aramid fire-retardant fabric to use for experiments, with tweezers (need candle for burn test).</li> <li>5. Samples of surgical masks cut in half for examination.</li> <li>6. Spray bottle for experiments for 2 and 3 above.</li> </ol>

STEM LESSON	LESSON AND HANDS-ON ACTIVITY DESCRIPTION	SUPPORTING MATERIALS NEEDED
<p><b>LESSON 5</b> Analyze <b>applied design</b> (printing) in fabrics (<i>LEVEL Intermediate</i>)</p>	<p>Lesson explaining block printing and silk screening process. <b>Hands-on Activities:</b> (Project group) block printing and resist printing (supplies such as fabric and dyes/fabric paint will be furnished by leader).</p>	<ol style="list-style-type: none"> <li>1. Wooden blocks, roller stamp, stencils.</li> <li>2. Sponge and stencil brushes.</li> <li>3. Samples of block printing.</li> </ol>
<p><b>LESSON 6</b> Explain how fabrics are made from various <b>natural resources</b> (<i>LEVEL Intermediate</i>)</p>	<p>Lesson exploring most common natural fibers (cotton, wool, flax, silk) and process from fiber to garment. <b>Hands-on Activities:</b></p> <ol style="list-style-type: none"> <li>1. Examining fabric from natural fibers.</li> <li>2. Viewing DVD about natural fibers.</li> <li>3. Looking at natural fibers under the microscope.</li> <li>4. Transformer match game.</li> </ol>	<ol style="list-style-type: none"> <li>1. Microscope.</li> <li>2. Slides, slide covers, small cup, medicine dropper.</li> <li>3. Fabric made from natural fibers.</li> <li>4. Wool fibers, cotton fibers and silk cloth (use to make slide to look at using microscope).</li> <li>5. Silk cocoon (to look at only).</li> <li>6. DVD — Clothing Fiber.</li> <li>7. Instructions for making slides. Kit contains five Transformer Match Game boards and corresponding pieces.</li> </ol>
<p><b>LESSON 7</b> Understand the process of making <b>manufactured</b> fabric (<i>LEVEL Advanced</i>)</p>	<p>Lesson is PowerPoint explaining process of making Manufactured Cellulosic and Synthetic fibers, including information about specific fibers and their use (rayon, acetate, nylon, polyester, acrylic, olefin, aramid). <b>Hands-on Activities:</b></p> <ol style="list-style-type: none"> <li>1. Learn about process of making manufactured fiber from leader and handout.</li> <li>2. Examine specific manufactured fiber fabrics and describe.</li> <li>3. Borrow DVD from Lesson 6 explaining various manufactured fibers.</li> </ol>	<p>Samples of Manufactured Fabrics:</p> <ol style="list-style-type: none"> <li>1. Samples of polyester, nylon, rayon, acetate, aramid, polypropylene/olefin.</li> <li>2. Different polyester samples to show variety.</li> <li>3. Carpet made of olefin.</li> <li>4. Acrylic (fake fur).</li> <li>5. Spool of polyester filament yarn.</li> <li>6. One magnifying glass.</li> <li>7. (DVD in Kit 6 can be used to show acrylic, nylon and polyester).</li> </ol>
<p><b>LESSON 8</b> Analyze the use of <b>nontraditional natural sources</b> to make fabric (<i>LEVEL Advanced</i>)</p>	<p><b>Hands-on Activities:</b> Examine products made from nontraditional natural sources.</p>	<ol style="list-style-type: none"> <li>1. Sample of corn fiber.</li> <li>2. Sample of hemp rope.</li> <li>3. Garment samples (two samples from among clothing made of bamboo, milk, containing insect repellent).</li> <li>4. Two examples of fabric made from microfibers.</li> </ol>



STEM LESSON	LESSON AND HANDS-ON ACTIVITY DESCRIPTION	SUPPORTING MATERIALS NEEDED
<p><b>LESSON 9</b> Experiment with different <b>fabric finishes</b> related to intended finished product use (<i>LEVEL Advanced</i>)</p>	<p>Lesson with information about various functional finishes.</p> <p><b>Hands-on Activities:</b> Experiment with fabrics, applying special finishes and testing differences.</p>	<ol style="list-style-type: none"> <li>1. Examples of fabric with special finishes.</li> <li>2. Large squares of muslin for Scotchgard and starch tests.</li> <li>3. Large squares of polyester and nylon to compare muslin sample.</li> <li>4. Spray bottle.</li> <li>5. Scotchgard spray.</li> <li>6. Starch spray.</li> <li>7. Small squares of fabric for wrinkle test.</li> <li>8. Balloons.</li> </ol>
<p><b>LESSON 10</b> Analyze the of <b>Smart garments</b> by today's youth for convenience in technology (<i>LEVEL Advanced</i>)</p>	<p>Lesson with information about Smart garments and new technology used in clothing and shoes.</p> <p><b>Hands-on Activities:</b> Research how to light up your clothes through using LED lights sewn to clothes and try it.</p>	<p>Materials needed to make circuit to illuminate an applique:</p> <ol style="list-style-type: none"> <li>1. Coin cell battery holders.</li> <li>2. Coin cell batteries.</li> <li>3. LED's 3mm.</li> <li>4. Conductive thread.</li> <li>5. Fabric.</li> </ol>
<p><b>LESSON 11</b> Identify the parts of the <b>sewing machine</b> and how it works (<i>LEVEL Beginning</i>)</p>	<p>Lesson covering parts of the sewing machine and basic use with crossword puzzle.</p> <p><b>Hands-on Activity:</b> Making a pillow.</p>	<ol style="list-style-type: none"> <li>1. Fabric for making a pillow.</li> <li>2. Sewing supplies.</li> <li>3. Sewing machine.</li> </ol>
<p><b>LESSON 12</b> Discover what causes <b>stains</b> on fabric and experiment with how to get them out (<i>LEVEL Intermediate</i>)</p>	<p>Lesson covers the concepts of what happens to fabric to cause stains when spills take place, types of stains and removing stains.</p> <p><b>Hands-on Activity:</b> Removing stains from fabric.</p>	<p><b>Supplies needed:</b></p> <ol style="list-style-type: none"> <li>1. Newspapers or plastic to protect surface, permanent pen/marker, cotton tip swabs, two 1-gallon plastic bags.</li> <li>2. 100 percent cotton fabric.</li> <li>3. Detergent without enzymes and bleach (Arm &amp; Hammer or Ivory Snow).</li> <li>4. Detergent with enzymes and bleach (Tide with bleach).</li> <li>5. Plastic spoon, dishpan of cool water, paper towels and various stains: ketchup, mustard, grape juice, soy sauce.</li> </ol>

STEM LESSON	LESSON AND HANDS-ON ACTIVITY DESCRIPTION	SUPPORTING MATERIALS NEEDED
<p><b>LESSON 13</b>  Ingredients in <b>laundry detergent</b> and their purposes  <i>(LEVEL Intermediate)</i></p>	<p>Lesson covers the science behind how clothes get clean, the components of detergent and their functions.</p> <p><b>Hands-on Activity:</b> Experiment to determine the difference in the cleaning capacity of natural vs. synthetic detergents.</p>	<p>Supplies needed:</p> <ol style="list-style-type: none"> <li>1. Newspapers or plastic to protect surface; bath towel, two 1-quart plastic containers.</li> <li>2. Permanent pen/marker.</li> <li>3. 100 percent cotton muslin fabric.</li> <li>4. Plant-based (natural) detergent (Mrs. Meyer’s Laundry Detergent; Charlie’s Soap).</li> <li>5. Petrochemical-based detergent (Tide, Cheer).</li> <li>6. Substances to stain fabric: ketchup, butter, orange juice, makeup.</li> </ol>
<p><b>LESSON 14</b>  Determining the <b>cost of making vs. buying clothes</b>  <i>(LEVEL Intermediate)</i></p>	<p>Lesson explains factors to consider when making the decision whether to buy or make garments including how to calculate the actual cost of each.</p> <p><b>Hands-on Activity:</b> Calculating the cost of making and buying clothes. Formula included in lesson.</p>	<p>Worksheet to use included in lesson.</p>

## STEM ACTIVITY 1: Learning About Fabrics— Fabric Weave and Knit Structures

### Understanding Textiles (Fabric)

#### STEM concepts you will learn:

1. The science behind various weave and knit structures determining how fabric is made.
2. The science behind why knit fabric stretches through the group stretch activity.
3. To measure the stretch of fabric and use a formula to determine percentage stretch.

#### Clothing and Textiles Project

**Outcome:** Identify the differences in woven and knit fabric.

**Indicator:** Identify fabrics as either woven or knit structures, completing at least one activity.

#### TIPPS Outcomes:

6<sup>th</sup> Grade Head, Thinking

- Use the senses to gain new information or find new ways to use information.

7<sup>th</sup> Grade Hands, Working

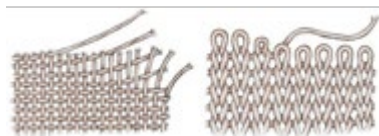
- Make appropriate use of equipment, tools and technology.

As we select clothes to wear on any given day, there are a lot of reasons we pick a specific garment. One important reason is for comfort. The fabric the garment is made from can determine comfort. Knowing how the fabric is made can help you know how it will feel, if it will be durable, and if it will stretch. In this activity you will learn the difference between woven and knit fabric, as well as specific construction techniques.

Weaving fabrics is an old art, taking place at least 9,000 years ago in the Middle East. While the speed of weaving has increased dramatically in recent years, the basic process and patterns have remained the same.

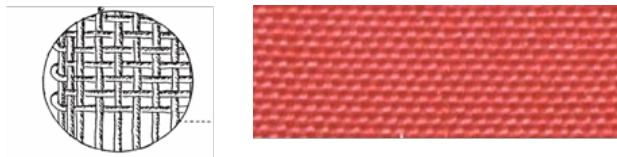
Woven fabrics can be characterized generally by their stability, with little give (elasticity). This means that you need closures such as buttons, zippers or snaps to get in and out of garments made from woven fabrics.

Weaving is the interlacing of yarns. **Warp** yarns run vertically in fabric and are the strongest yarns. **Filling** yarns run the width of fabric.



### Woven Fabrics

**Plain weave** — Interlacing warp and filling yarns, over one and under one. This is the most common weave used in woven fabrics. Common plain weave fabrics are chiffon, calico, gingham and muslin.



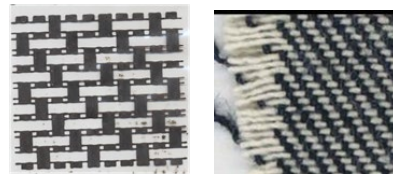
**Plain rib weave** — Unbalanced plain weave with larger filling yarns woven into smaller warp yarns. Common plain rib weave fabrics are taffeta, broadcloth and faille.



**Plain basket weave** — Two or more warp and/or two or more filling yarns used side by side as if they are one yarn. Common plain basket weave fabrics are monk's cloth and canvas cloth.



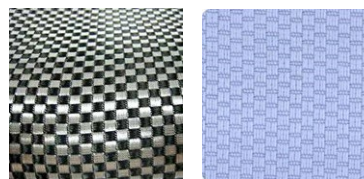
**Twill weave** — A diagonal effect is created by weaving over two and under one, then beginning the next row one yarn over. This is the most durable of the weaves. Common twill weave fabrics are denim, gabardine and herringbone twill.



**Satin weave** — Yarns float over several yarns before going under one, creating a high luster (shine). This fabric is typically used in dressy shirts, formal dresses and wedding gowns. Common satin weave fabrics are satin and sateen.



**Dobby weave** — Small, repeated, geometric patterns. Common dobby weave fabrics are bird's eye, pique and waffle cloth.



**Jacquard weave** — Complex weave with elaborate patterns. Fabrics made of this weave are used in formal



gowns as well as draperies and upholstered furniture. Common jacquard weave fabrics are brocade and damask.

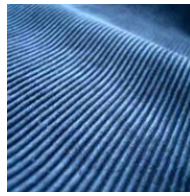


**Woven pile weave** — Has body and depth.

**Wrap piles** — Extra yarn inserted in warp direction. Common wrap pile weave fabrics are velvet and terry cloth.



**Filling piles** — Extra yarn inserted in filling direction. Common filling pile weave fabrics are velveteen and corduroy.



**Slack tension weave** — By holding some warp yarns tight and others loose, a puckering effect is created. A common slack tension weave fabric is seersucker.



### TEST YOUR FABRIC KNOWLEDGE

Circle T (True) or F (False) for each of the sentences below.

- |   |   |   |
|---|---|---|
| 1. Denim fabric is made using a satin weave.                  | T | F |
| 2. Plain weave is the most common weave used in woven fabric. | T | F |
| 3. Velvet is an example of a pile weave fabric.               | T | F |
| 4. Woven fabric generally has a lot of stretch.               | T | F |
| 5. The jacquard weave is used to make brocade fabric.         | T | F |

Answer: 1. F, 2. T, 3. T, 4. F, 5. T

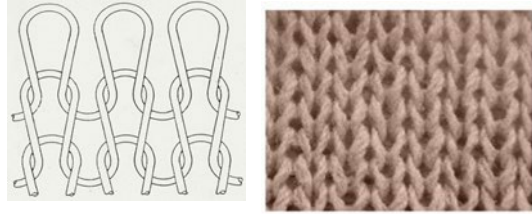
## Knit Fabrics

Most everyone wears garments of some kind made from knit fabrics, from T-shirts to underwear. But why do we like knit fabrics? Knit fabrics are known for their stretch. This makes garments very comfortable to wear. Knit fabrics also do not wrinkle as much as woven fabrics, are softer, and they generally cost less to make.

Knit fabrics are formed by interlooping yarns. As you learn about fabrics that are made through the knit process, you will learn that some of these fabrics do not stretch very much while others have lots of stretch.



The lengthwise loops of knit fabric are called the **wale**, while crosswise loops are called the **course**.



**Plain (Jersey) knit** — Can be identified by the vertical/diagonal loops on the surface. Typical garments made of plain knit include T-shirts, knit dresses and hosiery.



**Rib knit** — Can be identified by deep ridges on the fabric surface. The rib knit is one of the knit fabrics with the most stretch. Typical garments made from rib knit are cuffs and collar bands on sweatshirts, some sweaters, knit hats and tops of socks.



**Double knit** — Is characterized as having an interlocking extra set of yarns, which makes it thicker and less stretchable. All kinds of garments can be made from double knit fabric.



**Tricot knit** — Is very thin, usually made from synthetic fibers, and does not stretch very much. Typical garments made from tricot knit are lingerie, nightwear, blouses and dresses.



**Raschel knit** — Is an open-knit structure, often with visible holes, which makes it a less sturdy structure. Some raschel knit has closer loops and is thicker fabric. Typical garments made from raschel knit include any lace garment, some shirts and athletic wear.



### Activities to Do:

Now that you have learned about different types of fabrics, share this with your classmates, family or fellow 4-H'ers. Here are some ideas:

- Examine the fabric of some of the garments you wear and identify the fabric as woven or knit. Use a magnifying glass to make it easier.
- Visit a fabric store. While there, find and identify fabrics of the different weaves and knit structures. Be sure to take your magnifying glass with you.
- Research online information about woven and knit fabric characteristics.
- Find someone in your community who weaves or knits fabrics and learn about the process.
- Create a poster that identifies various woven and knit fabrics using fabric samples. Display it at a county fair or present to fellow 4-H'ers at a meeting or project group.

## Taking It to the Next Step: Experiments for 4-H'ers and Project Groups

### Fabric Weaves and Knit Structures Hands-On Experiment #1 — Let's Stretch It!

#### Goal:

To learn the difference in the stretchability function of woven vs. knit fabrics.

**Supplies needed:** 5 yards of jersey knit fabric with ends sewn together and 5 yards of firmly woven fabric with ends sewn together.

**Note:** This activity should always be supervised by an adult who reminds participants to keep the tube of fabric above the shoulders to below the hips at all times.

#### What to do:

1. **LEAN OUT:** Have approximately six participants stand inside the knit fabric band with their backs against the band (from their necks to their calves) and begin to move backwards. When the band is fully stretched, the leader will ask the participants to extend their legs toward the center of the circle and lean backwards fully supported by the band.



This exercise helps the group learn about the stretchability of knit fabrics.

Ask the group questions about their experience:

- a. Did you expect the fabric to have enough strength to support the group?
  - b. What did you learn about the knit fabric?
2. **LET'S ROLL:** Have a group of six participants stand inside the knit fabric band, stretching it only enough to keep it from falling to the ground. The leader will instruct each member of the group to begin to roll around the interior of the band in the same direction at the same time. Keep enough space between each participant to reduce accidental tripping. Ask participants to talk about how the fabric behaved as they moved around the tube.
  3. **LEAN OUT AND LET'S ROLL USING WOVEN FABRIC:** Have the same group of six try the same experiments with the firmly woven fabric.

Ask the group the following questions:

- a. Did the woven fabric give as much as the knit when you leaned back on it?
- b. Did you feel less like you were going to fall when you leaned back on the woven fabric?
- c. Why do you think this is so?
- d. What are some differences in the knit and the woven tube?
- e. Have the participants name some garments that would be suitable to make from the knit fabric and then from the woven fabric.

**Fabric Weaves and Knit Structures**  
**Hands-On Experiment #2 — Stretch That Fabric!**

**Goals:**

1. To learn the difference in the stretchability function of woven vs. knit fabrics.
2. To learn about the elongation and recovery of fabric that is stretched.

**Supplies needed:** Strips of woven and knit fabric 4 inches by 10 inches and a tape measure.

**Definitions:**

Elongation — The amount a stressed fabric is extended, expressed as a percentage of the original length.

Recovery — Recovery is the ability of a material to return to its original state when a stress is removed.

**What to do:**

1. In pairs, work together. Starting with the strip of **knit fabric**, measure the unstretched length by laying the fabric flat on a table. One partner holds the fabric flat, while the other uses the tape measure and measures the length. Record it here:

Measurement of unstretched knit fabric = \_\_\_\_\_

2. Now, have one person hold one end of the fabric in place while the partner stretches the fabric as far as possible. Record measurement as the “stretched length.” (Note: Record number in decimals instead of fractions. Ask for help if needed.)



Measurement of stretched knit fabric = \_\_\_\_\_

3. Let go of one end of the stretched fabric and observe how the fabric behaves with the stress removed. Record whether it returns completely to its original state or not. Also, record whether it returns right away or slowly.

Record findings here = \_\_\_\_\_

4. Now, calculate the percent elongation using the following formula:

$$\frac{\text{Stretched length} - \text{Initial Length}}{\text{Initial Length}} = \text{Elongation percentage in decimal points}^*$$

\*Make this number a percentage by multiplying it by 100.

Calculated percentage = \_\_\_\_\_



Repeat these steps using the woven fabric strip.

1. Measure the unstretched length of **woven fabric** by laying the fabric flat on a table. One partner holds the fabric flat while the other using the tape measure, measures, reads the length and records it here.

Measurement of unstretched woven fabric = \_\_\_\_\_

2. Now, have one person hold one end of the fabric in place while the partner stretches the fabric as far as possible. Record this measurement as Stretched Length. (Note: Record number in decimals instead of fractions. Ask for help if needed.)

Measurement of stretched woven fabric = \_\_\_\_\_

3. Let go of one end of the fabric and observe how the fabric behaves with the stress removed. Record whether it returns completely to its original state or not. Also, record whether it returns right away or slowly.

Record findings here = \_\_\_\_\_

4. Now, calculate the percent elongation using this formula:

$$\frac{\text{Stretched length} - \text{Initial Length}}{\text{Initial Length}} = \text{Elongation percentage in decimal points}^*$$

\*Make this number a percentage by multiplying it by 100.

Calculated percentage = \_\_\_\_\_

Answer the following questions comparing both tests.

1. Which fabric elongated least?
2. Why do you think this fabric did not elongate?
3. Would this fabric be a good choice for athletic apparel?
4. Which fabric elongated the most?
5. Why do you think this fabric elongated so much?
6. Did this fabric snap back to its original shape?
7. How does this quick recovery make this fabric ideal for a t-shirt?
8. What did you learn from this experiment that you will use if you buy fabric to make a garment or buy clothes?

Activity created by Sue Byrd, Professor Emeritus, University of Tennessee at Martin.  
Elements of this activity were adapted from [styleengineers.org](http://styleengineers.org).

## STEM ACTIVITY 2: How Clothes Get Their Color

### Understanding Textiles (Fabric)

#### STEM concepts you will learn:

1. The chemistry behind how fibers, yarns and fabric absorb dyes.
2. Technology and equipment used for various types of dyeing techniques.



#### Clothing and Textiles Project

**Outcome:** Identify the dyeing process for various fabric types.

**Indicator:** Tie-dye project completed.

#### TIPPS Outcomes:

6<sup>th</sup> Grade Head, Thinking

- Understand the meaning of information.
- Use the senses to gain new information or find new ways to use information.

6<sup>th</sup> Grade Hands, Working

- Make the needed effort to carry out a task or a plan.

When we buy a garment or home decorating item, one factor influences us the most in what we purchase. What do you think it is? **Color.** Have you ever looked at all the different colors of clothing that are available and wondered how the color gets there? Fabrics may in the raw stage (like wool or cotton) have a slight color, but without dyes our clothes would indeed be boring.

In this activity you will learn that:

- Colors in fabrics can come from dyes.
- Some dyes come from nature and some are produced in a laboratory.
- Dyes can be added to fabric at many different stages of production.

**Natural dyes** come from things in nature like plants, insects and minerals. A grass stain is an example of a dye from nature.

Many different colors can be achieved from nature. Until 1856 that was the only way to color fibers. In 1856, the first synthetic or laboratory produced dyes were developed. Natural dyes can be made from blackberries, marigolds, onion skins, red cabbage, indigo and walnut hulls. Tea can also be used as a dye.



Today almost all clothing and home decorating items you buy in stores are dyed with **synthetic dyes.**

**How are fabrics dyed?** Think of a dye being like Jell-O particles. Once they are put in solution (sometimes water), they dissolve and soak through the fiber, becoming part of the fiber or yarn. A chemical reaction makes them part of the fiber or yarn. Dyes can be added at most any stage of the textile production process. This includes:

- During dyeing the fibers (fiber dyeing);
- Dyeing the yarns (yarn dyeing);
- Dyeing the fabric or piece goods (piece dyeing); or
- Dyeing the end product.

The earlier the dyeing takes place in the process, the better the color penetration (even color and longest lasting). Manufactured fibers can even be dyed as they are being made. This happens when color is added to the solution being used to make the fiber. Natural fibers cannot be dyed this way. Some fibers may absorb dyes better than others.

Most fibers that we say are comfortable to wear (example: cotton) also breathe or absorb moisture and accept dyes well because of their high absorbency. These we would say “take” the dye better. Others that do not absorb moisture well (example: polyester) will not accept dyes well unless treated specially for this purpose or dyed by special ways and using special dyes.

### Creating Patterns on Fabric

In addition to dyeing fibers to make solid colors, we also wear clothes that have different patterns and designs on the fabric. **There are many different ways to make designs. Here are a few.**

- Dye can be applied in certain patterns by using a “direct” dye technique. Block printing is an example of this technique where the dye is applied to the block and it is “stamped” on the fabric. A roller printing machine will do the same thing. The design is raised on the roller, and when the dye is applied and then rolled over the fabric it stamps the fabric. This includes making paisley, calico and floral patterns.
- Tie-dye is a “resist” type of fabric dyeing where a pattern of color is made by preventing the dye from reaching some areas of the fabric while dyeing others.



### Be Creative Through Tie-Dye

Have you ever wanted to wear clothing you designed? You can through the tie-dyeing.

By folding, tying, crumpling or otherwise preparing the fabric, the flow of the dye is inhibited to some areas. Examples follow of how to make specific designs. The way the fabric is folded or tied with a rubber band and places where the dyes are squirted will determine the resulting design. With experience, the end result can be predicted and controlled to some extent, but surprise is part of what makes tie-dye an exciting and interesting art form — and there will be plenty of surprises.



#### Where did tie-dye come from?

Contrary to popular belief, tie-dyeing was not invented in 1960s America. Different forms of tie-dye have been practiced in India, Japan and Africa for centuries. The earliest surviving examples include pre-Columbian alpaca fabric fragments found in Peru and silk from fourth century Chinese tombs. Indian Bandhani, one traditional form of tie-dyeing, began some 5,000 years ago.

Japanese tie-dye is included among the many techniques of shibori, which has been used for many centuries to make different types of beautiful patterns on cloth used for elaborate kimonos.

As in ancient times, we still use natural fibers for tie-dyeing. Silks from China, cottons from Egypt and rayon from Bali are still highly prized. Many cultures still use tie-dye today to create beautiful fabrics and garments.

**Want to learn more?** Search the Internet using the key words “History of Tie-Dye.”

## How to Tie-Dye

### Supplies:

clothing or an item you wish to dye*	rubber bands or strings	marbles or round stones
dye, can be different colors	apron or old clothes	empty dishwasher-safe squeeze bottle or spray container
soda ash or salt	disposable aluminum pan	

\*T-shirts are the most often used, but you can use any white item. Make sure it is at least 60 percent cotton.

### Steps:

1. Before you dye your item, wash it to remove any sizing from the manufacturer or anything else that may have gotten on it. Soak your item in a soda ash solution for 10-20 minutes to set color or prevent fading. While wearing gloves, wring out the material.
  - a. How to make a soda ash solution: Mix a solution of 1 cup of soda ash per gallon of hot water until dissolved. (If you don't have soda ash, add ½ cup of salt to your dye solution.)
2. Decide the design you want your finished project to have.
3. Cover your work area so the dye doesn't stain it. Lay down a few large garbage bags and then put newspaper on top of that.
4. Lay your wet item out flat on a clean surface. Then fold and tie, using rubber bands, as desired. Try some of the examples that follow.
5. Prepare your dye as directed by the manufacturer. While preparing the dye and dyeing your item, you should wear rubber gloves to protect your hands from staining and the hot water plus an apron or old clothes.

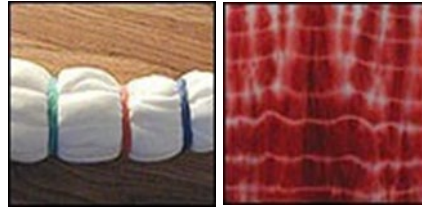
Note: For best results either use less water or more dye than instructed.

6. Now, you are ready to start dyeing. Fill empty dishwashing liquid bottles or empty spray containers with the color(s) of dye you are using. Hold your item over a large disposable aluminum pan. Squirt or spray the areas where you want the color.
7. Lay on a protected surface. Allow the dye to soak in for 15 minutes before rinsing. Suggestion: You can put this in a plastic bag so the dye can be absorbed for several hours. Then rinse thoroughly, remove your rubber bands or strings and rinse again.
8. Admire your creation!
9. Be careful washing your tie-dyed items! Most should always be washed in cold water. The first few times they are washed, they might bleed, so wash them with like colors or alone.



**Here are some examples of patterns:**

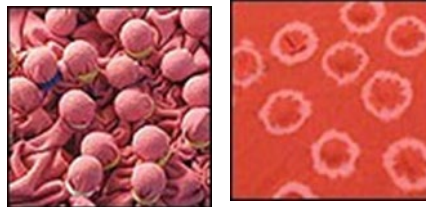
A. Lines = use rubber bands at intervals



B. Sunburst = use marbles and rubber bands



C. Circles = one marble and one rubber band repeated all over the item/fabric



**TEST YOUR KNOWLEDGE**

1. Name a natural substance that can be used to dye fabric: \_\_\_\_\_
2. (True or False) Dye can be added to synthetic fibers as they are made.
3. (True or False) Fibers such as cotton that are comfortable and absorbent also dye well.
4. (True or False) Today most of the dyeing of fibers/fabrics is done using natural dyes.
5. What is the dyeing technique called where blocks are used to create a design?  
\_\_\_\_\_
6. Name a country besides the United States where tie-dyeing has been done:  
\_\_\_\_\_

Answers to "Test Your Knowledge":  
1. Berries, flowers, ... 2. T, 3. T, 4. F;  
5. Direct dyeing;  
6. India, Japan, China

**What can you do with what you have learned?**

- A. Try dyeing a white garment using natural dyes such as tea.
- B. Go online and find instructions on how to dye fabric using substances from nature and try it out.
- C. Meet with younger 4-H'ers and teach them about tie-dyeing and have them create their own tie-dye.
- D. Create a poster or PowerPoint with information about the history of tie-dye and share with others.
- E. Interact with a person from another country and learn more about their culture.
- F. Have someone take a picture of you making an item and save it to use later in making posters of your activities, scrapbook and a portfolio.

## Taking It to the Next Step: Experiments for 4-H'ers and Project Groups

### How Clothes Get Their Color Hands-On Experiment #1 — How to Identify How Fabric Is Dyed

#### Goal:

1. Identify the dyeing process for yarns and fabric.

**Supplies needed:** Samples of yarns and fabric using various dyeing techniques. Ask your leader, parent or grandparent who sews or does crafts with yarns for yarns and fabric for this activity.

#### **What to do:**

You will look at yarns and fabric to determine how they get their color. Do the following:

1. For fabrics, pull a few yarns (threads) from the edge of the fabric.
  - a. If each thread is a solid color, then the fabric is made of yarn-dyed yarns. An example is check gingham or denim.
  - b. If you are looking at one thread from a fabric and you see multiple colors, then it is printed fabric. An example is calico fabric.
  - c. If the fabric is a solid color, it is most likely dyed after the fabric is woven, which means it is fabric dyed.
2. For yarns, use those that are used in craft projects, such as for crocheting or knitting. Cut a 3-inch piece of yarn from the yarn sample. Untwist the yarn.
  - a. If you see all one color, then the yarn is dyed after the yarn is formed or yarn dyed.
  - b. If the different strands (fibers) that make up the yarn are different color, then yarn is fiber dyed.

Using the above as a guide, examine the fabric and yarn you have collected. Create a chart such as the one below to record your findings.

SAMPLE	HOW IT IS DYED		
	(CIRCLE 1)		
Fabric Sample 1	Yarn Dyed	Fabric Dyed	Printed
Fabric Sample 2	Yarn Dyed	Fabric Dyed	Printed
Fabric Sample 3	Yarn Dyed	Fabric Dyed	Printed
Yarn Sample 1	Yarn Dyed		Fiber Dyed
Yarn Sample 2	Yarn Dyed		Fiber Dyed

What did you learn?

Activity created by Sue Byrd, PhD, Professor Emeritus, University of Tennessee at Martin.  
Elements of this activity were adapted from Kansas 4-H Clothing Leaders Notebook.

## STEM ACTIVITY 3: Investigating Fabrics that Keep You Warm

### Understanding Textiles (Fabric)

#### STEM concepts you will learn:

1. The physics and chemistry behind why certain fabrics keep you warmer than others.
2. The engineering behind how products are designed by industry to keep you warmer.
3. Through mathematical evaluations, the insulative performance of various fabrics by completing a thermal wrap activity.

#### Clothing and Textiles Project

**Outcome:** Compare thermal function of various fabrics for warmth.

**Indicator:** Testing various fabric types for thermal qualities.

When there is a chill in the air, we begin to pull out our jackets and sweaters in order to stay warm. In general, fabric tends to insulate us by trapping air to reduce heat loss. This may be due to the fiber used, the way the fabric is knit or woven, or the texture or bulkiness of the fabric. (Fibers are the smallest part of a yarn that is used to weave or knit to make fabrics.)



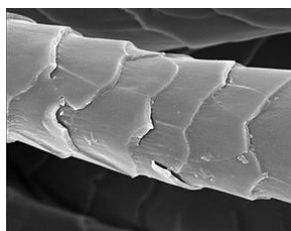
In this activity you will learn the specifics of how different fabrics keep you warm.

#### What Determines the Insulative Value of Certain Fabrics?

When taking a closer look at the fabrics that are used to make the clothes we wear, there are many factors that determine the insulative value of any particular garment. First, if a garment has good insulative value, it keeps the heat generated by your body from escaping. Let's look at some specific examples in order to better understand this concept.

#### FIBERS WITH BULK

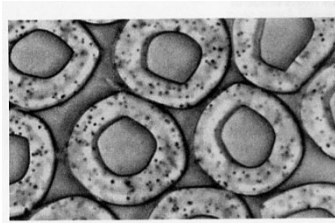
Some fibers, such as wool, are bulky which allows air to be trapped between the fibers in the yarn. In fact, if you take a really close look at a wool fiber under the microscope, you will see what are called scales. They make the fiber a good insulator that holds in the heat your body generates. Wool fibers also have a special quality in that they do not absorb moisture, and the overlapping arrangement of the scales causes them to shed water like the shingles of a roof. Some water particles can slip in between the scales, causing the fabric to feel wet on the outside while being dry on the inside. ([weatherwool.com/pages/the-science-of-wool](http://weatherwool.com/pages/the-science-of-wool))



WOOL FIBER

## MANUFACTURED FIBERS WITH INSULATIVE VALUE

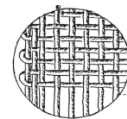
**Hollow Fibers:** Some manufactured fibers (fibers made in a laboratory) are made with spaces within the fiber filled with air. Thermolite is a brand of the fabric made from these fibers. It works by speeding up the process of moving moisture from the skin to the fabric's exterior so it can evaporate quickly. Keeping your skin dry is important in staying warm. It is recommended to use Thermolite clothing with other garments for a layered effect. Thermolite fabric is used to make jackets, socks, gloves and ski wear. Here's a fun fact: DuPont, a fiber manufacturer, invented Thermolite. They got the idea by studying the hairs of polar bears, which are hollow.



hollow fibers

What a difference the weave makes!

If you take a closer look at the fabric your clothes are made of, you will find that the fabric is either woven or knit. As a general rule, woven fabric does not stretch while knit fabric does. Woven fabric is made using various types of weaving patterns. The closer the weave in the fabric, the higher the insulative value and the warmer you will stay.

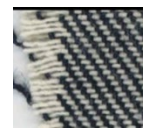


plain  
weave



woven  
shirt

Here is an example: A woven shirt is most often made using a plain weave, which is an “over-one-under-one” pattern, while denim jeans are made using a twill weave fabric that creates a diagonal effect. The twill weave is the strongest and tightest weave of all the weaves. Therefore, a garment made using a twill weave fabric will keep you warmer than one made from plain weave fabric.



twill  
weave



denim  
jeans

## THE INSULATIVE VALUE OF KNIT GARMENTS

If you think about why you wear knit-based garments, there are probably three main reasons: 1) they stretch, so they are easy to get off and on, 2) they are comfortable because they don't bind the body, and 3) the fabric is usually soft.

Look at the garments you have that are knits and you will find a variety from T-shirts to sweaters. Which keep you warmer? Probably your sweaters. Part of the reason is that sweaters are bulkier, which creates more air space to trap your body heat.



Some sweaters are three-dimensional, which further traps air. A sweater made using a cable knit design as shown to the right, is an example. Think of your T-shirts, similar to the example on the left. They are usually thin, so you have to add layers to help create air space to keep you warmer.



Another tip related to T-shirts: if you use them as part of layering, check your labels and make sure you are not wearing 100 percent cotton T-shirts. The reason is that cotton absorbs

moisture from your skin and retains it, which will make your skin feel clammy, damp and cold. Instead choose T-shirts that are 50 percent cotton and 50 percent polyester. Polyester does not absorb moisture.

### Other Fabrics that Keep You Warm

**Fleece:** Anyone who spends any time outdoors has heard of fleece fabric. Fleece is a soft insulating fabric made from a thermoplastic polymer resin of the polyester family used in synthetic fibers. Plastic bottles are often recycled to make fleece. These synthetic fibers are used to create an extremely lightweight fabric that is superior to the insulating properties of wool. The fabric is made up of many lofted synthetic fibers that trap air, which keeps the heat from your body close to you.



**Quilted Fabric:** As stated earlier, if you wear layers of clothing, quilted fabric will keep you warmer. Quilted fabric that might be used for a vest or jacket has three layers of fabric that are stitched together. It consists of two layers of fabric with some kind of thick fiber layer in between. This layer is usually nonwoven fibers/fabric but could also be down feathers. Sometimes ripstop nylon is used for the outer layer, which keeps wind and rain from penetrating. So, in addition to keeping heat in, quilted fabric can keep the elements of weather out.





## Test Your Knowledge

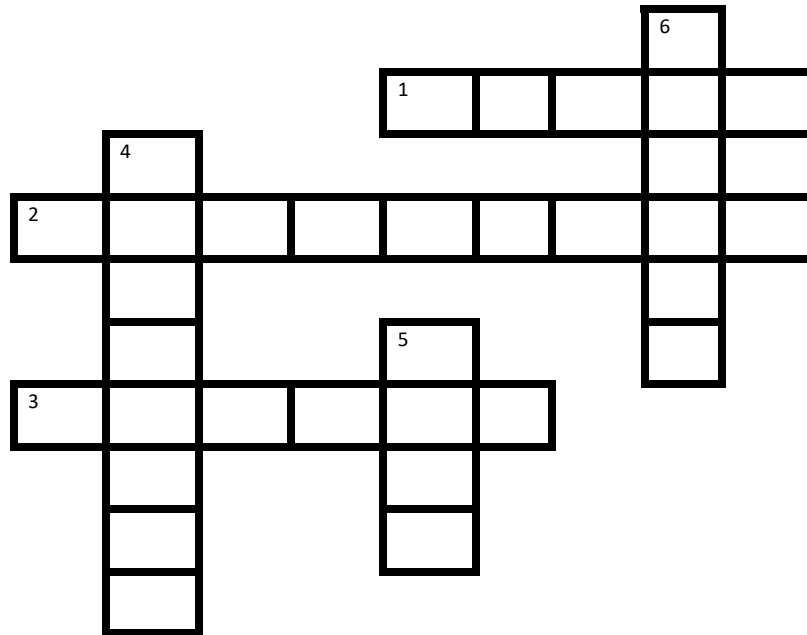
Now, find out what you have learned about how fabric keeps you warm by completing this crossword puzzle:

### ACROSS

1. The name of the weave that is the tightest weave, thus keeping you warmer.
2. To aid in keeping you dry when you sweat and are wearing layers, a T-shirt should be 50 percent cotton and 50 percent \_\_\_\_\_.
3. Thermolite clothing keeps you warm because the fibers they are made from are \_\_\_\_\_.

### DOWN

4. The fibers often used on the inside of quilted fabric.
5. The fiber that has scales, which is water repellent and keeps you dry and warm.
6. The name of the fabric that is sometimes made from recycled plastic bottles.



Answers to crossword: 1. Twill 2. Polyester 3. Hollow 4. Nonwoven 5. Wool 6. Fleece

## Taking It to the Next Step: Experiments for 4-H'ers and Project Groups

### Investigating Fabrics that Keep You Warm Hands-On Experiment #1 — Thermal Qualities of Fabrics for Warmth

Fabrics can be good **insulators** against **conductive** heat loss because fibers and fabrics often trap air within their structures. Some manufactured fibers have interior spaces filled with air, while fibers, such as wool, have a bulky texture that traps air between fibers in yarns and fabric. Fabric construction (woven vs. knit), thickness, weight, density and surface texture affect the amount of trapped air, and therefore a fabric's effectiveness as an insulator. Layering multiple fabrics can increase the insulative performance of a garment as well by trapping additional air between layers or blocking airflow through fabrics.

#### Goal:

To compare the insulative performance of different fabrics through personal experimentation.

**Supplies needed:** 3 yards each of different fabrics (different weights and weaves — shirt weight woven fabric, fleece, jersey knit, etc.), infrared laser temperature gun, timer, magnifying glass.

- a. Note: Clothing of different fabric could be used, but needs to be large enough for everyone to wear. For group leaders — these supplies may be available through your 4-H agent through the Extension Family and Consumer Sciences Regional Office.
- b. Tip: Caution participants to not point the laser gun at anyone's eyes. Groups may prefer recording data on a large communal chart (poster, newsprint, chalkboard or Smart Board) for easier viewing and discussion.

#### What to do:

1. Touch the fabric, noting the thickness, weight and surface textures.
2. Next, examine the fabric with a magnifying lens to identify its structures (woven or knit) and the density (thickness) of the construction. Record your observations in the **fabric description** column of the Thermal Wrap Activity Sheet.
3. Based on observations in Step 1, predict the fabric's performance by ranking the samples from 1 (warmest/best insulator) to 5 (coolest/worst insulator). Record those numbers under **prediction**.
4. Using the temperature gun, read the subject's body temperature at rest by pointing the device at the back of the neck. Record that temperature under **before exercise**.

Note: Have all but the person doing the experiment stand to the side or behind the "subject."

5. Participants should wrap themselves in the fabric they are testing and jump up and down or run around for three minutes. See an example in the picture to the right.
6. Using the temperature gun, read the subject's body temperature by pointing the device at the back of the neck while the subject is still wrapped in the test fabric. Record that temperature under **after exercise**.
7. Repeat steps 1-6 for the other fabrics and other participants.
8. Take two of the fabrics and create a layered effect by putting them together and repeating steps 2-6. Do this with the different fabric combinations. Repeat the steps again.





### Thermal Wrap Experiment Worksheet

Description of Fabric	Prediction of Insulative Performance  (Rank 1, best/warmest to 5, worst/coldest)	Temperature			Results of Insulative Performance  (Rank 1, best/largest increase to 5, worst/smallest increase)
		Before Exercise	After Exercise	Change (After – Before)	

Activity created by Sue Byrd, Professor Emeritus, University of Tennessee at Martin.  
Elements of this activity were adapted from styleengineers.org.

## STEM ACTIVITY 4: The Science Behind Fabrics that Protect

### Understanding Textiles (Fabric)

#### STEM concepts you will learn:

1. The chemistry of how synthetic fibers are produced.
2. Why chemical finishes are added to fabrics for extra protection against the environment.
3. The technology behind how nonwoven fabrics are made.

#### Clothing and Textiles Project

**Outcome:** Compare protective function of various fabrics.

**Indicator:** Completed activity examining and testing selected fabrics.

Have you ever wondered how special fabrics work that protect us and professionals in various situations? Here are some examples to think about: How do raincoats and umbrellas keep us dry? How do bulletproof vests protect police officers? How do surgical masks keep germs from spreading?

In this activity, you will explore the science behind these special fabrics and more.

**Nylon** is often used in products that protect you against the rain. Products include raincoats, umbrellas and tents. Nylon has many desirable properties, including being tough (strong); lightweight; water resistant; easy to wash; and dries quickly.

To make nylon truly waterproof for outerwear, tents, etc., it is given a coating of resin. Resin is a sticky substance that is not soluble in water and is used to protect a fabric.

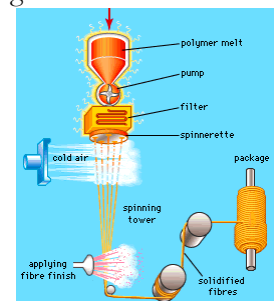
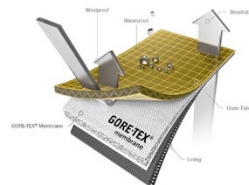
Unfortunately, nylon does not let water vapor pass through it, which means nylon water-resistant clothing traps sweat. Eventually, the inside of the clothing becomes wet and unpleasant to wear.



#### Nylon production

Nylon fiber is produced by pushing molten (liquid) nylon through tiny openings in a device called a spinnerette. The nylon pieces then harden into a filament (string-type substance) after they are exposed to air. These filaments are collected and stretched once they have cooled down. A process known as drawing further stretches the filaments or yarn, which are then wound onto a spool. This procedure makes the molecules in the filament form parallel lines, which provides the nylon fiber with its elasticity and strength.

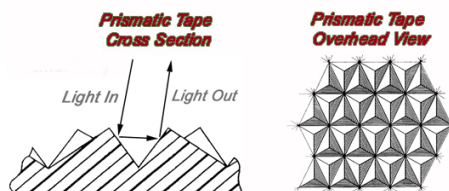
**GORE-TEX** is an amazing breathable, waterproof fabric used in clothing worn for outdoor activities. GORE-TEX stops rain from getting in, but let's perspiration out. So, it keeps you dry on the outside and dry on the inside at the same time. GORE-TEX isn't one material. It's actually a sandwich of three layers. There are two layers of nylon making up the "bread" and a layer of microporous Teflon in between. How can GORE-TEX be both waterproof and breathable at the same time? Here's the science behind this. Steam caused by perspiration passes out easily because the water molecules are smaller than the pores in the GORE-TEX liner; water droplets can't get in the other way because they're much bigger.





**Reflective strips.** Have you ever wondered how reflective strips (tape) actually work? They light up only in the dark. Here is the science behind the tapes:

1. Reflective tapes reflect light through small microprisms built into the tape.
2. These tapes use small prisms that reflect light. Look at the pictures to the right.
3. The angle of reflection can be changed depending on the desired results.
4. The brightest of tape reflects most of its light back to the source. This makes the tape brighter. For more information go to: [colebrothers.com/articles/reflective\\_tape.html](http://colebrothers.com/articles/reflective_tape.html)



**Hospital surgical masks** function by stopping microorganisms (germs) from entering or exiting the mask. The filters that make up the mask must allow the wearer to breathe while trapping particles. The design of the surgical masks usually includes three layers made up of **nonwoven** fabric with the middle layer being melt-blown material that is what actually stops germs. Melt-blown means the fibers that start as small plastic beads are melted and formed into short fibers, then actually blown onto a surface to create fabric. Most surgical masks feature pleats or folds. The mask's three-ply structure is made into a single mask by using an ultrasonic heat-sealing machine that seals the outside edges of the three-ply layers.



**Protective clothing** is used by agricultural workers to wear when applying pesticides. In the agriculture production industry, pesticides are often used for weed and pest control. It is important to cover the whole body with a protective covering in order to prevent the pesticide from being absorbed through the skin. The labels on the pesticides will specify that the user wear personal protective equipment (PPE), such as gloves, clothing, eye protection and respirators (face masks). Chemical-resistant clothing is either reusable or disposable.



- A. **Reusable clothing** is most often made of laminated woven or nonwoven fabric, such as rubberized rainwear. This provides excellent protection against most pesticides. Reusable clothing is sometimes heavy and uncomfortable in hot conditions.
- B. **Disposable protective clothing** is made of spun-bonded (nonwoven) fabrics that do not absorb pesticides as quickly as woven materials. The term spun-bonded means that continuous strands of synthetic fiber are blown on a surface and in the process, tangled together and bonded with a sticky substance. The most popular type of spun-bonded disposable clothing is made of Tyvek. This type of material provides an effective barrier from several pesticide sprays and dusts.



**Bulletproof clothing** provides police officers and military personnel with protection. The process of producing specific bulletproof fabric uses a chemical blend and spinning it into a solid thread. These threads are intertwined into a cord. Here are the basic steps:

1. Raw Materials — Synthetic fibers that are lightweight but strong are used. One of the most well known is Kevlar.
2. Yarn Production — Large spools of the basic fiber are used to weave those individual fibers into cords and yarn.

3. Sheet Materials — The yarns are then woven into a layer of material that is capable of stopping bullets.
4. Cutting the Material — Using large industrial cutting machines, multiple layers of ballistic material are cut at once. Generally, bulletproof clothing consists of front and back panels that are a slightly different shape and size. The panels used in bulletproof clothing consist of multiple layers of this material.
5. Assembly — The proper thickness of the fabric layers is assembled to create the ballistic panel and stitched together.
6. The Cover — The sewn layers of ballistic material then need to be put into a protective envelope that is heat sealed to protect the ballistic material inside against water and humidity.
7. Carrier — These panels are then fitted into a specially designed carrier with pockets in which the ballistic panels can be inserted.

**Wet suits.** When you think of a wet suit, the first thing that comes to mind is probably scuba diving. Wet suits are used for scuba diving, whether for sport or as part of industry-related jobs where individuals are in the water to keep them warm and dry. What is the chemistry behind how the fabric used in a wet suit keeps you dry? The fabric is made up of carbon and hydrogen atoms called polychloroprene, which form a long-chained molecule that is linked together. Other substances are attached to add bulk, adhesion, color, etc. This results in a doughy mixture that is pressed together using heat, forming a “sheet” of fabric. A fabric called *neoprene*, which is waterproof and stretches, is created.



Note: Certain types of wet suit material are not waterproof, but trap a thin layer of water against a diver's body. While the diver still gets wet, his body rapidly heats up the thin layer of water trapped against him close to body temperature. If the suit fits properly, the warm layer of water does not circulate away from the diver's body.



**Fire protective fabrics.** There are many jobs today that require individuals to wear garments that are flame resistant or fire retardant. This includes firefighters, welders, workers in the oil and gas industry, chemical plants and others. What makes the fabrics from which these garments are made resistant to catching on fire? Here are the facts:

1. Certain fabrics are manufactured to be fire retardant. An example is NOMEX, which is made from a fiber called Aramid.
2. For other fabrics that need to be flame resistant, chemical finishes are applied. This is done in one of two ways:
  - a. Special chemicals are applied to a manufactured fiber as it is made, changing the molecular structure of the yarn that will last for the life of the garment.
  - b. For cotton and cotton blends, the finish is applied after the fabric is made either through a gas infusion process or applying heat to the fabric after the special chemical substance is added.



For more about this process go to [textilemates.com/manufacturing-flame-resistant](http://textilemates.com/manufacturing-flame-resistant) or search the internet using the term “flame-resistant fabric process.”

**What can you do with what you have learned?**

- Learn more about these specialty fabrics by exploring information on the internet and talking to people who use these products.
- Make a poster for an exhibit with pictures and information to share.
- Organize a project group and have a firefighter, scuba diver or other professional who uses protective garments talk to the group.

## Taking it to the Next Step: Experiments for 4-H'ers and Project Groups

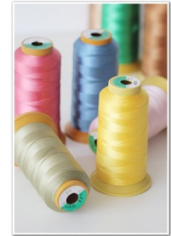
### The Science Behind Fabrics that Protect Hands-On Experiment #1 — Don't Get Wet. Nylon Can Protect You!

Nylon is not completely waterproof; it is water resistant because it is made of a synthetic substance that repels water naturally. Nylon is also water resistant because the weave of the fabric is tight or close together, which keeps water out. The third reason why nylon is water resistant is a coating is often applied to nylon fabric that is intended for use in producing raincoats, umbrellas, etc., in order to make the fabric truly waterproof.

#### Goal:

To test nylon to show its waterproof capacity.

**Supplies needed:** Ripstop nylon fabric 8 inches by 10 inches (nylon fabric used for raincoats and umbrellas), spray bottle and plastic tub



Note: You can use an umbrella for this experiment. For Group Leaders: the supplies for these experiments may be available through your 4-H agent through the Extension Family and Consumer Sciences Regional Office.

#### What to do:

1. Have one person hold one side of the nylon fabric sample and another participant hold the other side of the fabric vertically over the plastic tub.
2. Take a spray bottle with water and spritz using a fine mist the nylon (or umbrella) three to four sprays, simulating rain. Hold the spray bottle 8-10 inches away from surface of the fabric.
  - a. You can continue to spray the fabric to see what level of saturation will cause dampness on the back of the fabric. The results will depend on the fabric used.
3. Have participants feel the back side of the nylon for dampness.
4. Ask participants why they think the fabric stays dry based on what they know.

## The Science Behind Fabrics that Protect

### Hands-On Experiment #2 — Want to Go Scuba Diving? Will You Get Wet?

#### Goal:

To test fabric used in wet suits.

**Supplies needed:** Wet suit fabric sample (e.g., neoprene), spray bottle and plastic tub



Note: Fabric can be purchased online, if it is not available from a local fabric shop.

#### What to do:

1. Have one participant hold one side of the neoprene fabric and another participant hold the other side of the fabric vertically.
2. Take a spray bottle with water and spritz the neoprene repeatedly three to four times.
3. Have participants feel the back side of the nylon for dampness. Ask them why they think the fabric stays dry based on what they know.
4. Pour a cup of water on the same side of the fabric.
5. Have participants feel the back side of the nylon for dampness.
6. Have the participants come to a conclusion based on this experiment.

## The Science Behind Fabrics that Protect Hands-On Experiment #3 — Let's Test Aramid for Flame Retardancy

### Goal:

To determine the flammability of Aramid.

**Supplies needed:** small squares of aramid fabric, tweezers, candle or another flame source



Note: Fabric can be purchased online, if it is not available from a local fabric shop. Be sure to use caution when using a candle indoors. Consider doing this experiment outside.

### What to Do:

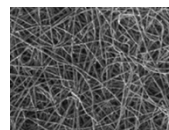
1. Have participants gather around to observe this experiment.
2. Place a fabric square of Aramid between tweezers.
3. Light a candle and move the fabric into the fire, removing it after it ignites.
4. Ask the participants to talk about what they observed.

Note: The fabric will ignite slightly while in the flame but will extinguish itself when removed. The sample does not actually burn like other fabrics and will keep its basic structure.



## The Science Behind Fabrics that Protect Hands-On Experiment #4 — How Does that Mask Work?

**Nonwoven fabrics** have fibers bonded together by mechanical bonding (fiber entanglement), chemical bonding (fibers are chemically bonded together with glue-like compounds), or thermal bonding (where low-melt fibers are used and heat melts the fiber to each other). Nonwoven fabrics are lighter and weaker than woven or knit fabrics.



**Woven fabrics** are produced on a loom. The loom joins two sets of yarns by weaving one set between the other. Woven fabrics are durable to washing and can be finished to yield many different properties (like being flame-retardant or water-repellant). They do not have much stretch because of the tightness of the yarns in the fabric.



**Knit fabric** uses knitting to form a fabric by means of interlooping the yarn. Knitting machines do the same interlooping of yarn that a hand knitter does. Knit fabrics have stretch because of the looseness of the fabric's yarn structure (compared to wovens and most nonwovens). Because of this looseness, the fabric can tighten up due to the mechanical action in laundering. That's why knit fabrics shrink. Knit fabrics are comfortable and warm.



### Goal:

To examine a surgical mask and learn more about nonwoven fabrics.

**Supplies needed:** surgical mask cut in half

### What to Do:

1. Have the participants talk about what a surgical mask is used for (and other masks) and how it works based on the information in STEM Activity 4, Protective Function of Fabric.
2. Discuss the differences in nonwoven, woven and knit fabric using the information below. You may also show images of each.
3. Have the participants examine the inside of the surgical mask and talk about the different layers.

## The Science Behind Fabrics that Protect Hands-On Experiment #5 — Why Do We Wear Camouflage?



**Camouflage** is the use of any combination of materials, coloration or illumination for concealment, either by making animals or objects hard to see or by disguising them as something else. Examples of camouflage include:

- The leopard's spotted coat.
- The battle dress of a modern soldier.
- The leaf-mimic katydid's wings.

The majority of camouflage methods aim for concealment, often through trying to resemble the background. Some animals, such as chameleons and octopuses, are capable of actively changing their skin pattern and colors, whether for camouflage or for signaling. It is possible that some plants use camouflage to evade being eaten.

Military camouflage was spurred by the increasing range and accuracy of firearms in the 19th century. On land, camouflage is designed so the wearer will blend in with the surroundings, such as trees and foliage or desert.

Non-military use of camouflage includes making cellphone towers less obtrusive and helping hunters to approach wary game animals.

### **Goal:**

To learn about forms of camouflage.

**Supplies needed:** Clothing made of camouflage fabric.

### **What to Do:**

1. Ask participants to answer the following questions and discuss:
  - a. What is camouflage?
  - b. Do certain animals use camouflage and if so, which ones?
  - c. Why is camouflage worn by humans?
2. Show camouflage shirt or other items

Activity created by Sue Byrd, PhD, Professor Emeritus, University of Tennessee at Martin. Elements of this activity were adapted from Texas Cooperative Extension, [sciencing.com/nylons-properties-uses-8627049.html](http://sciencing.com/nylons-properties-uses-8627049.html), [nap.edu/read/11637/chapter/4](http://nap.edu/read/11637/chapter/4), [bodyarmornews.com/how-is-bulletproof-clothing-made](http://bodyarmornews.com/how-is-bulletproof-clothing-made), [sciencing.com/neoprene-made-6587118.html](http://sciencing.com/neoprene-made-6587118.html), and [barnhardtcotton.net/blog/case-blending-purified-cotton-nonwovens](http://barnhardtcotton.net/blog/case-blending-purified-cotton-nonwovens).

## STEM ACTIVITY 5: How Designs Are Made on Fabric

### Understanding Textiles (Fabric)

#### STEM concepts you will learn:

1. The science behind resist and direct printing.
2. The technology used in direct printing.

#### Clothing and Textiles Project

**Outcome:** Analyze applied design (printing) in fabrics.

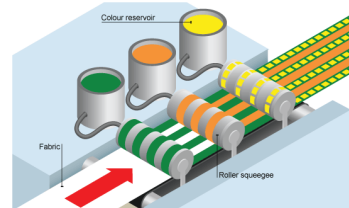
**Indicator:** Completed project using applied design.

When we think of the clothes we wear, often we do not consider how the fabric is actually created or how the color or design on the fabric actually gets there. Take a look in your closet at your clothes. You should see some that are solid colors and some that contain different designs. In this activity you will explore what is called Applied Design, the design on the fabric that is made using one of several processes.

There are two basic categories of applied design: 1) direct printing and 2) resist printing.

**Direct printing** is the process by which a pattern is created on fabric by applying the pattern directly onto the fabric. Have you ever used an ink stamp to stamp a date on a piece of paper? The concept is the same. In producing fabric, several different pieces of equipment can be used to print a design directly onto fabric.

- a) **Block printing** is one of the oldest forms of printing. It uses wooden blocks that have a design carved into them. Then, dye is applied and the block is pressed into the fabric. This process is repeated to create the design throughout the fabric. In India, this technique is used quite often. It is not easy to repeat patterns using block printing. It takes great precision.
- b) **Roller printing** is more often used to produce designs/patterns on fabric. This process uses a huge roller that spans the width of the fabric. The design is engraved on the roller. Dye is applied to the roller, which is then rotated on top of the fabric. A separate roller is used for different colors and different parts of the pattern. The result of using roller printing is a very precise print, since the rollers are set up on a machine to repeat the design at the proper distance from the first design to produce an overall pattern.



#### Experiment #1

Now that you have learned about direct printing, it's time to actually apply what you have learned. See the end of this lesson for the Basics of Block Printing. Here are some suggested activities.

1. Examine a garment you own with a design or pattern on the fabric. Determine what the pattern is and see if you can find where the pattern repeats. Take it one step further and get a piece of fabric that has a design/pattern on its surface. Determine what the pattern is and where the design repeats. With a marker draw a square or rectangle around the design so you can clearly identify the pattern and where it repeats.
2. Create your own block under the supervision of an adult by taking a raw, large white potato. Cut it in half long ways. Draw a simple geometric pattern on the surface and carefully cut away the part of the

potato that is not in the pattern. Now, take fabric paint and use either white paper or plain fabric and create your own design by applying paint to the pattern and pressing it in place. Repeat the process.

3. Ask your 4-H leader or parent to purchase a wooden block with a design carved on it or rubber stamps and use them to create your own designed fabric.

**Resist printing** occurs when an area of the fabric is covered or protected when dye is applied. The following are examples of resist printing techniques.

- a) **Screen printing** is a type of resist printing that uses a pattern with gaps in it for the design, which is burned onto a screen using a special exposure light. Ink (dye) is pushed into the pattern, leaving color on the fabric through the gaps in the pattern. A separate screen must be used for each color that is part of the design. The designs on many of the T-shirts you wear today that have a slogan or design on the front are made by screen printing.
- b) **Stencil printing** is printing involving the use of stencils cut into the shape of the desired designs. The stencils can be made of metal, wood, paper or plastic. The dye/color is applied with a brush on the spaces cut in the stencil. This is a very easy method of printing on fabric.
- c) **Batik** is another example of resist printing that uses wax to cover the area of the fabric the artist does not want the dye to penetrate. The fabric is immersed in a dye bath. The areas without wax are dyed, while the design covered in wax remains white. From here, this process can be repeated depending on the design desired. By applying wax to different areas and dipping the fabric in different colored dyes, the artist can achieve complex multicolored designs. Batiking is a folk-art technique used in many countries to create wall hangings and other crafts that reflect the culture and/or traditions of that country.



## Experiment #2

Resist printing is more complicated than direct printing and needs specialized equipment. The easiest form to try is stencil printing. Your local craft store has a large selection of stencils to choose from. You will need to also buy stencil brushes and paint and 100 percent cotton plain fabric. Read the “Tips for Successful Stenciling” at the end of this activity sheet before starting your project. Have fun experimenting with creating repeated designs with your stencil or one design. You can also stencil on T-shirts or other clothing items, but be sure to slip a piece of cardboard between the front and back of a garment so the paint won’t bleed through. You need to work on a hard surface.

## Other Ways of Printing Fabric

With advanced technology, there are many new ways being discovered to print fabric. Among them include:

**Heat Transfer or Thermal Transfer** printing involves using a printing machine and a heat press machine to transfer designs on fabric. This process involves printing the design on paper first and then the design is transferred to the fabric by passing both through hot rollers.

**Digital Textile** printing or direct-to-garment printing involves printing on fabric using modified inkjet technology (similar to how a printer you may use to make copies works).

**Photo Printing** takes place by coating the fabric with a chemical that is sensitive to light and then printing a photograph onto the fabric.

## Basics of Block Printing

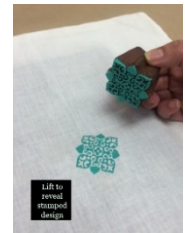
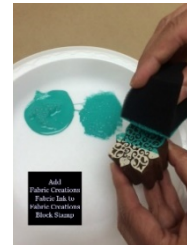
1. **Choose your fabric and supplies** — You will need fabric paint, a foam brush, purchased block, rubber stamp or your own created block, and 100 percent cotton fabric. Heavier weight fabric works best — for example, canvas fabric.
2. **Prepare the fabric** — To remove sizing, prewash your fabric in hot water using water and detergent. Iron while damp for a smooth working surface.



Note: Be sure to do this especially if you are block printing on something you will wear or use in your home, like a pillowcase.

3. **Reinforce your work** — Place fabric on a flat surface such as smooth glass or cardboard. Place protective material between your artwork and the flat surface.
4. **Adjust paint consistency** — Put a small amount of paint on a plastic or styrofoam plate. Apply paint evenly onto a piece of foam or foam brush. If the paint is too thick, spritz it lightly with water. Before applying to fabric, check the image by applying it on paper and then a scrap piece of fabric. Continue until you are pleased with the results.

5. **Stamp the fabric** — When you are ready to apply your design to your fabric, first apply the paint to your block with the foam brush, then press onto the fabric and wait a second for the fabric to absorb it. Repeat the process. For help check out this [link](#).



6. **Clean between colors** — Thoroughly clean the block between colors. A coarse fabric combined with the cleaning solution makes a great stamp cleaner. Use a toothbrush to clean recessed areas of the stamp. To protect your stamps, clean them before storing.
7. **Save your paint for later** — If you must leave your project for a while, don't forget to save your paint for later. Close your paint container. Place the plate you have used for your paint and foam brush in an airtight container or bag. When you're able to get back to your project just spritz the paint with water. You will need to clean your block as the paint will dry quickly.
8. **Let it dry and heat-set your work** — Follow the paint manufacturer's instructions and let your work dry completely. If the manufacturer recommends heat-setting your work, you'll want to make sure that the paint is completely dry so you don't spread wet ink/paint with the iron and always use a piece of fabric between your work and the iron.

## Tips for Successful Stenciling

1. **Use the right fabric.** Cotton is a great choice — it has a smooth surface but absorbs a good amount of paint. That’s why you see so many projects on canvas bags, T-shirts and quilting cotton. When you move into synthetic fibers, things get tricky. The paint slides around on the surface, doesn’t want to adhere to the fabric, and wants to bleed under the stencil. So, know your fabric.
2. **Make it stick.** Fabric moves and shifts. If this happens you will have blurred edges. So, what to do? Two things:
  - a. Secure it to your surface with some tape. You can use a piece of cardboard or another stiff surface for this.
  - b. Tape stencil to the fabric using painter’s tape. You might also spray the back of the stencil lightly with temporary adhesive that will further hold it in place. One recommendation is using 505 adhesive spray, but make sure you spray **LIGHTLY**.
3. **CAUTION, don’t use too much paint.** The goal is to get some color on the fabric without overloading it. If you glob on the paint, it has to go somewhere, and most of the time it is going to bleed under the edges of the stencil onto the fabric. You need to load the brush with paint and then get rid of the excess before you start applying it. Dip your brush in the paint a few times and then tap (lightly brush) it on a paper towel to get all the excess paint off. This is called offloading. Your brush should be almost dry before you start putting down the paint. You only want to apply a thin coat by stippling — using an up-and-down motion or small tight swirls. Try to work your way in from outside the stencil. You do not want to push paint under the edges when you stipple. You can find some videos on YouTube demonstrating this process if you search for stenciling tips. **Practice your technique** on a scrap of fabric to test the paint level and perfect your technique. Watch to see that the imprint looks uniform and fairly dry (see item 6 below).
4. **Apply the paint,** holding your brush vertically and touching the fabric with an up-and-down motion (which is stippling). The result will be a series of touches that bleed together in a process. Keep going until the entire area is the color you desire.
  - a. If the fabric looks a little wet as you continue, that is OK. It will even out as it dries.
  - b. To create crisp edges, do a gentle swirling motion. This will fill in these spaces with paint without leaving lines.
5. **Let it dry.** After you stipple, there should be a thin layer of paint on the fabric. Sometimes that is enough. If so, great! But sometimes it looks uneven or you want more coverage. Don’t do anything until you are sure your project is dry. Otherwise, if you add more paint now, you will just mush it all around and probably end up bleeding the stencil edges. So, wait at least until the paint has set before going back and adding another coat.
6. **Practice, practice, practice.** Do not just jump right in and start stenciling your main piece before testing everything on some scrap fabric, especially if you are dealing with materials, tools or techniques that are new to you. No one does everything right the first time! So, don’t mess up your project just because you want to get it done quickly! A good piece of scrap fabric lets you work out any kinks in your technique without the pressure of possibly messing everything up.

Activity created by Sue Byrd, PhD, Professor Emeritus, University of Tennessee at Martin.  
Elements of this activity were adapted from Textiles: Concepts and Principles and [walltostencils.com/howto](http://walltostencils.com/howto).



## STEM ACTIVITY 6: How Fabric Is Made from Natural Sources

### Understanding Textiles (Fabric)

#### STEM concepts you will learn:

1. Technology used to harvest and process fibers used to make fabric.
2. The engineering involved in processing fibers to make fabric.
3. The science behind what fibers look like and why.

#### Clothing and Textiles Project

**Outcome:** Explain how fabrics are made from various natural resources.

**Indicator:** Successfully complete one activity.

Have you ever wondered how the fabrics that your clothes are made from are formed?

It all starts with fibers. **Fibers** are the smallest part of a fabric that can be categorized into two major categories, natural or manufactured. In this activity, you will learn about the natural fiber sources and how these fibers are converted through modern technology to make fabrics.

Let's first look at which fibers fit into each category. Below you will find a list of common fibers used in clothing, divided into each category:

- |   |   |
|---|---|
| <p>I. Natural Fibers</p> <ul style="list-style-type: none"> <li>Cotton</li> <li>Wool</li> <li>Silk</li> <li>Flax</li> </ul> | <p>II. Manufactured Fibers</p> <ul style="list-style-type: none"> <li>Polyester</li> <li>Nylon</li> <li>Acrylic</li> <li>Rayon</li> </ul> |
|---|---|



To begin this exploration, do the following:

Look in your closet and pull out 10 garments that you wear often, but make sure you select those that are for different occasions (example: school, playing sports or exercising, relaxing at home, or wearing for a special occasion). This will give you a better picture of the variety of fibers used in making your clothing. Look at the labels of each and write down the fiber content of each garment (example: 50 percent polyester, 50 percent cotton).

	Garment	Occasion	Composition
1.			
2.			
3.			
4.			
5.			
6.			
7.			
8.			
9.			
10.			



From the list above, determine how many of your clothes fall into each category:

- I. Natural Source = \_\_\_\_\_
- II. Manufactured Source = \_\_\_\_\_
- III. Combination of Natural and Manufactured = \_\_\_\_\_

From your summary, which category contains more of your clothes? Circle your answer.

Natural

Manufactured

Why do you think this is so? List all the reasons you can think of by examining your clothes and the qualities they have that make you want to wear them. For example, soft, stretchy, etc.

As you explore the process of making your clothes from natural sources, reflect back on what you have discovered about what you wear.

### Sources of Natural Fibers

There are two major sources of natural fibers — plant and animal. As you explore these sources you will learn the science and engineering behind what it takes to transform each fiber into yarn and the fabric that is used for the clothing you wear.

#### Plant Sources

- A. **Cotton** is the most-used fiber in the world. It accounts for half of fiber used worldwide for clothing. Forty percent of our clothing is made of cotton. Cotton fibers are found around the seed of the cotton plant. The length of fibers determines the quality of the cotton. The longer the fibers, the smoother the feel of the cotton.



So, how does cotton get from the field to your back?

## Basic Process for Making Cloth from Cotton:

1. Growing cotton — Look at the map at the right to discover where cotton is grown. The United States, China and India are among other countries that grow cotton. One of the machines used to harvest cotton in the U.S. is the stripper harvester, which has rollers or mechanical brushes that remove the entire boll from the plant.



2. From the field, seed cotton moves to nearby gins for separation of lint and seed. The lint is the actual cotton fiber, which is formed into bales.



3. Several bales are mixed and blended together to provide a uniform blend of fiber properties.



4. The blended lint (cotton fiber) is blown by air from the feeder through chutes to cleaning and carding machines that separate and align the fibers into a thin web.



5. This is further refined through several processes and then spun into yarn.



6. Then, it's time for the fabric to be made. Depending on the end product, the yarn will either be woven or knit using automated machinery.



7. After the fabric is made and finishes applied, the fabric is dyed and is ready for making the clothes you wear. This happens in a clothing manufacturing plant.



Shirt made of woven fabrics



Shirts made of knit fabrics

What does the cotton fiber look like?



Under the microscope, cotton fibers look like twisted ribbons. When the fibers are growing in the field, they are round and hollow. After they are harvested, the fiber collapses, creating a flat fiber. Cotton clothing is usually soft to the touch and feels very comfortable to wear. It is very breathable.

- B. **Flax** is one of the oldest fibers known to man and has been found in ancient mummy burial sites. It comes from the stem of the flax plant. Fibers come in small bundles from beneath the outer covering of the stem. Flax is used to produce a fabric called “linen.” Cotton and flax are both plant materials. They are alike in many ways. They are called cellulosic fibers.



#### Basic Process for Making Cloth from Flax:

1. Harvesting is still done by hand. The plants are gathered and dried in the field.
2. A process called retting takes place to get the fiber from the inside of the plant, getting a bark-like substance off the outside.
3. Further processing is done before spinning the fibers into yarn.
4. Fibers/yarn can be up to 12 inches long.
5. The yarn is then woven into fabric and then made into garments and home products, such as tablecloths.

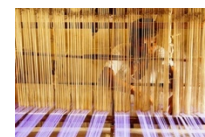


#### Animal Sources

**Silk** is one of the softest fabrics on the planet. It is shiny, breathable and comfortable. Silk has been a highly prized cloth since it was first harvested thousands of years ago. It is classified as a protein fiber, since it comes from an animal source.

#### Process of Making Silk Fibers into Cloth:

1. The fiber is harvested from the cocoons of silkworms. Silkworms are caterpillars of the *Bombyx mori* moth. The silkworm secretes a sticky liquid protein from its special salivary glands. Pushed through a spinneret (opening on the mouth), the twin pair of continuous threads harden when they come into contact with air.
2. To harvest the silk, the cocoon is placed in either boiling water or blasted with steam or hot air. The silk is reeled from the cocoon before the worm matures into a moth. This results in an undamaged (unopened) cocoon that gives a single long, fine fiber.
3. Raw silk strands are twisted together to make a relatively strong yarn.



4. The silk yarn is woven into fabric.



Silk fibers are very small compared to other fibers. Under the microscope they resemble spaghetti noodles, smooth and stringy. That is why silk fabric feels smooth and slippery. When we think of clothes that are made of silk, we usually think of dressy ones.

- A. **Wool** is another very old fiber and the first to be spun into yarns and woven. It comes from the soft fleece of sheep that are shaved (sheared) once or twice a year. The softest part of the fleece is the part next to the sheep, and the outer edges are used for rugs and felt. The best quality wool is a product of Merino sheep. They tend to grow thinner fibers that are longer. Countries that are major wool producers are Australia, Russia, New Zealand, China and Argentina. The United States is 10th in wool production.



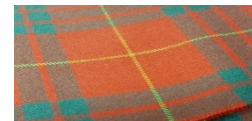
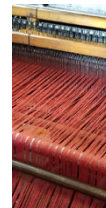
So, how does wool clothing get from the sheep to a jacket?

#### Basic Process for Making Fabric from Wool:

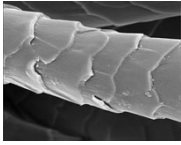
1. It all starts with the sheep who are sheared once or twice a year.
2. The fleece (which is what comes off the sheep) is cleaned.
3. An oily substance called lanolin is removed from the wool fiber.
4. The wool fibers are carded (aligned in straight rows).
5. These fibers are spun into yarn.



6. The yarns are dyed into the desired colors.
7. Next, the yarns are woven into fabric.
8. To make the surface become fuzzy (napped) and provide more warmth, the surface is “roughed up” using teasel (the top of the teasel plant that is dried).



9. The fabric is ready to use to sew jackets and other clothes you wear.
10. If the wool yarn is used to knit sweaters, after step 6 (above) the knitting takes place.



Wool fibers have special qualities that keep you warm and dry. If you take a really close look at a wool fiber under the microscope, you will see what is called scales. These make the fiber a good insulator, which holds in the heat your body generates. Wool fibers also have a special quality in that they do not absorb moisture, and the overlapping arrangement of the scales causes them to shed water like the shingles of a roof. Wool fabric is usually heavier and sometimes scratchy to the touch.

**Activities to Do:**

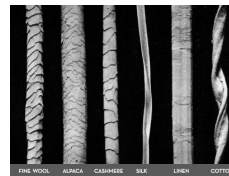
1. Take a closer look at your wardrobe and the fiber content of the clothing you most often wear. Compare this to the characteristics of the fibers you have learned about.
2. Visit a fabric store and find fabrics with the fiber content you learned about in this lesson.
3. Create a poster display focusing on one of the natural fibers in this activity and share it with others.

## Taking it to the Next Step: Experiments for 4-H'ers and Project Groups

### How Fabric Is Made from Natural Sources Hands-On Experiment #1 — Take a Look Under the Microscope at Fibers

**Goal:**

To discover what natural fibers look like close up.



**Supplies needed:** Microscope, slides, slide covers, tweezers, medicine dropper, fibers or fabrics of cotton, wool, silk.

Note: For project leaders, this may be available through your 4-H agent and/or Regional Extension Office. You may want to work with your local school and do this activity after school in a laboratory where they will have the supplies you need except fibers. The fibers can come from fabric that has the fiber content listed by pulling a thread and twisting the end with tweezers.

**What to do:**

1. For this activity you will create a wet mount microscope slide for each of the fibers: cotton, wool and silk. Use the image below to verify what you are seeing. Remember that there will be several fibers on one slide (below shows what just one fiber of each kind looks like).
2. To make a wet mount microscope slide:
  - a. Obtain a sample of fibers and place on clean slide with tweezers.
  - b. Place a few drops of water on the slide. If using a thread from fabric, use tweezers to untwist the end of a thread and fluff it up. Place that end of the thread on the slide and follow procedures above.
  - c. Next, apply the cover slip. This is done very gently in order to avoid the formation of air bubbles. Slowly lower the cover down at an angle, and it will eventually be held in place by surface tension.
3. Record what you see in the chart below.

FIBER NAME	DESCRIBE WHAT YOU SEE
COTTON	
WOOL	
SILK	
Mystery fiber (provided by leader) Identify the fiber by what you see: _____	

Discuss what you see and what you have learned.

Activity created by Sue Byrd, PhD, Professor Emeritus, University of Tennessee at Martin.  
Elements of this activity were adapted from *Textiles: Concepts and Principles* and [cottoninc.com](http://cottoninc.com).



## STEM ACTIVITY 7: How Manufactured Fibers/Fabrics Are Made

### Understanding Textiles (Fabric)

#### STEM concepts you will learn:

1. Technology used to create manufactured fibers used to make fabric.
2. The engineering involved in creating manufactured fibers to make fabric.
3. The science behind what manufactured fibers look like and why.

#### Clothing and Textiles Project

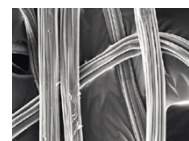
**Outcome:** Understand the process of making manufactured fabric.

**Indicator:** Successfully complete activities in the lesson.

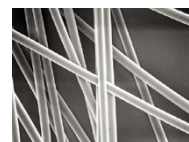
Have you ever wondered how the fabrics that your clothes are made from are formed?

It all starts with fibers. **Fibers** are the smallest part of a fabric that can be categorized into two major categories, natural or manufactured. In this activity, you will learn about how manufactured fibers are made. Manufactured fibers make up 70 percent of the textiles used in the U.S. today. Common characteristics of manufactured fibers include:

- Easy to control production;
- Ability to tailor product to consumer needs and desires; and
- Blending of manufactured and natural fibers produce desirable products.



rayon fibers



polyester fibers

The most commonly used manufactured fibers are polyester, nylon, acrylic and rayon.

To begin this exploration, do the following:

Look in your closet and pull out 10 garments that you wear often, but make sure you select those that are for different occasions (Example: school, playing sports or exercising, relaxing at home, or wearing for a special occasion). This will give you a better picture of the variety of fibers used in making your clothing. Look at the labels of each and write down the fiber content of each garment. (Example: 50 percent polyester, 50 percent cotton)



	Garment	Occasion	Composition
1.			
2.			
3.			
4.			
5.			
6.			
7.			
8.			
9.			
10.			



From the list above, determine how many of your clothes fall into each category (**Hint:** The most common natural fibers are cotton, wool and silk.):

- I. Natural Source = \_\_\_\_\_
- II. Manufactured Source = \_\_\_\_\_
- III. Combination of Natural and Manufactured = \_\_\_\_\_

From your summary, which category contains more of your clothes? Circle your answer.

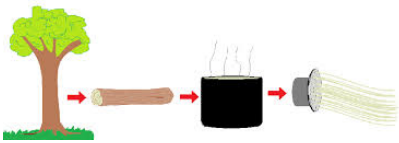
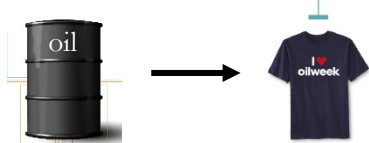
Natural

Manufactured

Why do you think this is so? List all the reasons you can think of by examining your clothes and the qualities they have that make you want to wear them. Example: soft, stretchy, etc. For those clothes that are made from manufactured sources, look and feel them and describe how they feel (shiny/dull, rough/smooth, etc.).

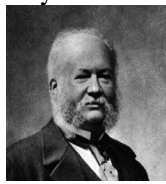
### Categories of Manufactured Fibers

There are two major categories of manufactured fibers: 1) regenerated cellulosic and 2) synthetic. As you explore these sources, you will learn the science and engineering behind what it takes to make these fibers and convert them to yarn and fabric.

Manufactured Cellulosic	Synthetic
	
cellulosic base	petroleum base
Example: rayon	Example: polyester

### Making Manufactured Regenerated Cellulosic Fibers

**Rayon** is the most common manufactured regenerated cellulosic fiber. Its claim to fame is that it is the oldest manufactured fiber. In 1884 a French chemist by the name of Hilaire de Chardonnet (picture to the left), in an effort to attempt to create artificial silk, discovered what is now called rayon.

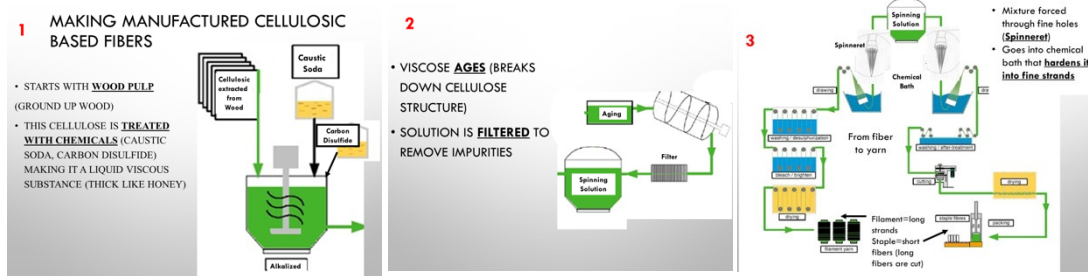


Rayon can be characterized as soft, lightweight and absorbent and is used for a variety of clothing, including lingerie, dresses and sportswear (see images to the right).



Most rayon production begins with *wood pulp*, though any plant material with long molecular chains is suitable. There are several chemical and manufacturing techniques to make rayon, but the most common method is known as the *viscose process*. In the viscose process, cellulose is treated with caustic soda (aka, sodium hydroxide) and carbon disulfide, converting it into a gold, highly viscous liquid about the color and consistency of honey. This substance gives its name to the manufacturing process called “the viscose process.”

Follow the process in the pictures from left to right:

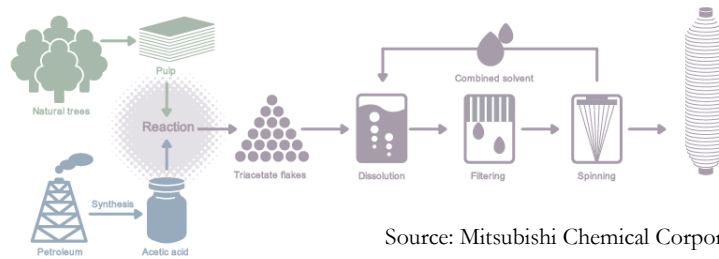


**Acetate**, another manufactured regenerated cellulosic fiber, originated in England in 1923 by a company named Celanese. Characteristics of acetate include:

- Shiny, smooth, drapable.
- Heat sensitive.

As you can see from the diagram below, the process of making acetate is similar to rayon, however petroleum is part of the process. It gives acetate more of the qualities of synthetic fibers.

Schematic Diagram of the Production Process for Acetate Fiber



Uses of acetate: dressy dresses, lingerie, linings, blouses and bedspreads



### Experiment #1

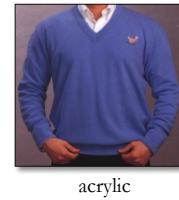
Look in your closet or get your family involved and ask them to look in their closets. Find garments made of rayon and acetate. Examine the fabric and determine if they have the characteristics listed in this lesson.

List these qualities here:

Rayon —

Acetate —

**Synthetic fibers** are a group of fibers that are primarily made by putting together simple chemical elements to make complex chemical compounds. They are mostly petroleum based.

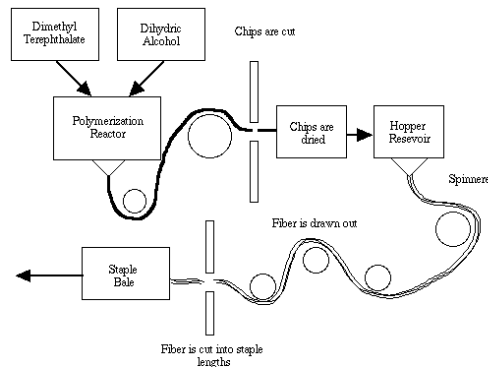


Characteristics of Synthetic Fibers:

- Heat Sensitive — needs low heat in dryer and low heat if ironing.
- Pilling — small balls of fiber will form on the surface of sweaters.
- Static Electricity Buildup — does not absorb moisture, so will cause static buildup.
- Oily Stains Problem — since they are oil based, food particles accidentally dropped on clothing that contain oil, such as fried food and ketchup; butter will cause stains.

### The Process of Making Synthetic Fibers

1. Polymerization: the process starts with condensation of acid and alcohol using high temperatures.
2. The substance created is pushed through cooling wheels to form *ribbon like a substance*.
3. The ribbon hardens and is cut into chips.
4. Spinning — The chips are dried and then put into a hopper (reservoir) for melting. Fibers are “Melt Spun,” which means they are heated and extruded through spinnerets and cooled upon hitting the air.
5. Drawing — The fibers are hot stretched to decrease their width. The fibers are then wound onto cones as filaments or are crimped and then cut into staple (short) fibers.



Source: [schwartz.eng.auburn.edu/polyester/manufacturing.html](http://schwartz.eng.auburn.edu/polyester/manufacturing.html)

## Experiment #2

Now that you know the basics of how synthetic fibers are made, let's look at three specific fibers and compare the fabrics in your closet made of these fibers with the known characteristics.

### Nylon

Characteristics	Test to do to determine if my clothing has the listed characteristic:	Do the clothes selected from my (or my family's) closet containing this fiber have this characteristic?	
		Yes	No
Doesn't Wrinkle	Take a corner of the garment and wad in your hand for 30 seconds. Let go and see if fabric wrinkles.		
Has Static Buildup	Rub your garment with a blown up balloon. See if the balloon will stick to the wall. (Has static built up?)		
Fast Drying	From your experience with washing this garment, does it dry quickly?		

### Polyester

Characteristics	Test to do to determine if my clothing has the listed characteristic:	Do the clothes selected from my (or my family's) closet containing this fiber have this characteristic?	
		Yes	No
Doesn't Wrinkle	Take a corner of the garment and wad in your hand for 30 seconds. Let go and see if fabric wrinkles.		
Has Static Buildup	Rub your garment with a blown up balloon. See if the balloon will stick to the wall. (Has static built up?)		
Fast Drying	From your experience with washing this garment, does it dry quickly?		
Pilling is a Problem	If you have a garment made of polyester that is older, are there small balls of fiber around the elbow or other areas of friction?		

### Acrylic

Characteristics	Test to do to determine if my clothing has the listed characteristic:	Do the clothes selected from my (or my family's) closet containing this fiber have this characteristic?	
		Yes	No
Doesn't Wrinkle	Take a corner of the garment and wad in your hand for 30 seconds. Let go and see if fabric wrinkles.		
Soft	Feel the fabric and compare the feel to a garment made of polyester.		
Warm	Put on garment and jump up and down for 30 seconds. Does it warm you up?		
Light Weight	Put on garment. Does the garment feel heavy or light?		

## Taking it to the Next Step: Experiments for 4-H'ers and Project Groups

### How Manufactured Fibers/Fabrics Are Made Hands-On Experiment #1 — Spinning a Thread (Making Synthetic Yarn)

**Goal:**

To experience the creation of handmade synthetic fiber.

**Supplies needed:** Nylon samples, glass rod, tweezers, candle

Note: In this experiment you will try to create a synthetic fiber. Be sure to have adult supervision.

**What to do:**

1. Create a hypothesis related to what will happen in this experiment based on the goal. There may be multiple hypotheses, so think outside the box.
2. Using a candle, fold the small nylon sample  $\frac{1}{4}$  inch by 1 inch and put it between tweezers.
3. Hold the glass rod in your other hand
4. Put the end of the nylon sample into the flame and quickly remove it (you want the edge of the sample to melt but not flame up).
5. Quickly touch the end of the glass rod to the part of the sample that was in the flame and has melted  
Note: Be careful not to let the nylon sample flame up. Have a container next to the candle to hold the nylon sample over in case it does flame up as it may drip.
6. Pull the rod away; you should see a thread form.
7. Try the process again until you spin the thread.

At the end of the experiment, analyze what happened and why. Dig deep for the possible answers to why.

Activity created by Sue Byrd, PhD, Professor Emeritus, University of Tennessee at Martin.  
Elements of this activity were adapted from Oeco Textiles – Textile Processing and Manufacturing, Mitsubishi Chemical Corporation  
– Fibers and Textiles, Acetate Fiber and Auburn University Schwartz Engineering – Manufacturing Polyester.

## STEM ACTIVITY 8: Fabrics Made with Nontraditional Natural Sources

### Understanding Textiles (Fabric)

#### STEM concepts you will learn:

1. The chemistry behind how microfibers are made.
2. The science behind how special purpose finishes are applied.
3. The technology used to make garments from nontraditional natural fibers.

#### Clothing and Textiles Project

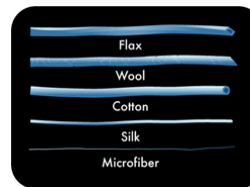
**Outcome:** Analyze the use of nontraditional natural sources to make fabric.

**Indicator:** Completion of one activity.

With today's technology, fabrics can be made of almost anything or be made to have qualities that we desire, such as wrinkle resistant, easy care, etc. Researchers are developing ways to use products that are readily available that can be converted to fabric while using ecofriendly techniques that help preserve our environment. This activity will focus on new technology used to create fibers from natural substances that you would not normally think of as being used for fabric.

### New Fibers Called Microfibers

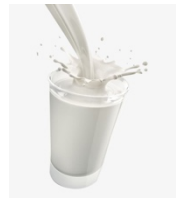
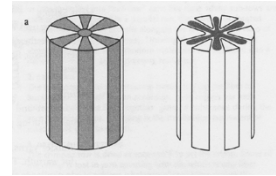
Before investigating new sources of fibers that are natural, let's look at new fibers that make our life easier called microfibers. **Microfibers** are made using new technology that allows fibers/fabrics to be made to look like anything you want — suede, leather, silk, athletic fabric and more. Look at the size of microfibers in the chart on the right and you can see how small they are compared to other fibers that we commonly use in our clothing.



How are microfibers made? To better understand the process, let's learn some definitions.

- **Denier** is a unit of measurement that is used to determine the fiber thickness of individual threads or filaments used in the creation of textiles and fabrics. Fabrics with a high denier count tend to be thick, sturdy and durable. Fabrics with a low denier count tend to be sheer, soft and silky.
- A **polymer** is a substance that has a molecular structure consisting chiefly or entirely of a large number of similar units bonded together.
- A **spinneret** is a device used to extrude a polymer solution or polymer melt to form fibers. Think of it like a shower head.

Microfibers are very small (<0.6 denier). They are made by using two incompatible polymers, extruded through a spinneret then separated. These polymers, such as nylon and polyester, will not stick together. Naturally, they come apart to form very small fibers, microfibers. Fabric made from these fibers includes sportswear fabric, cleaning cloths and mops, and suede fabric for clothes and upholstery. The fabric is very easy to care for and does not wrinkle.



You've always been told to "drink your milk." Now you can wear it, too!

**Milk fibers** belong to a class of bio-based manufactured fibers known as regenerated protein fibers. They are made from the protein casein, which can be separated from sour milk. Casein is dissolved in a solution and then forced through a spinneret to produce long strands, which are then stretched, heated and chemically treated to increase their strength and stability. In the past, unpleasant chemicals such as formaldehyde were used to strengthen the fibers. Today, most milk fibers are blended with a chemical binder, which is also the main component of acrylic yarn.



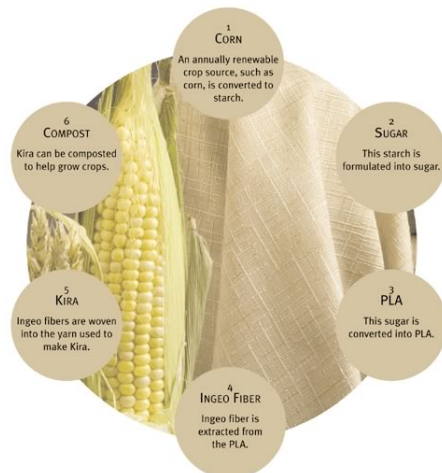
Products made from milk fibers: T-shirts, underwear, sportswear, ladies' outerwear, scarves, sweaters



Did you know that corn is an important agricultural product that has many uses? New technology is now using corn to make corn fibers that can be made into fabric for us to wear. Look at the picture below to see how this works.

Simply speaking: The raw materials are made by fermenting sugar extracted from corn. It is then turned into pellets that are converted into fibers by melting and spinning the pellets into fibers.

**Corn fibers** are called Ingeo fibers by the company that invented it. Corn (Ingeo) fibers are wrinkle free, drapable, hypoallergenic and wick away moisture. PLA in the diagram below stands for Polylactide Polymer, which is a long chain (polymer) of lactic acid. Kira is the name of the fabric made from Ingeo fibers. The production and use of corn fibers create less pollution and fewer greenhouse gases than making other fibers. This fiber "closes the loop" in the life cycle of plants since it can be recycled after it is worn for clothing to make compost to help grow crops.





**Bamboo fibers** are increasing in popularity. There are several reasons for this including that they are eco-friendly fibers and are grown using no fertilizer or pesticides. Fabrics made from bamboo are absorbent and have antimicrobial properties, which means growth of microorganisms is inhibited on fabric made of bamboo. This will keep the fabric from being susceptible to mildew or mold.

Bamboo Fiber Production Flow:

1. Raw bamboo.
2. Bamboo stripping.
3. Steaming.
4. Crushing and decomposing.
5. Biological enzyme degumming.
6. Fiber carding.
7. Natural bamboo fiber.



Products made from bamboo: sundresses, T-shirts, dress socks and bedding

### Using Industrial Hemp to Make Clothing Fibers

Today in the U.S. more and more agricultural producers are starting to grow industrial hemp, which is used to make many products, including paper, textiles, biodegradable plastics, construction, health food and fuel. It is one of the fastest growing biomasses known. It also runs parallel with the *green future* objectives that are becoming increasingly popular. Hemp requires little to no pesticides and no herbicides, controls erosion of the topsoil, and produces oxygen. Furthermore, hemp can be used to replace many potentially environmentally harmful products, such as tree paper (the processing of which uses chlorine bleach, resulting in the waste product called dioxins, which are carcinogenic, causing cancer).

Hemp fabric is soft on the skin and is known for growing softer with each wear. It's also naturally resistant to bacteria and provides natural UV protection. That means it protects your skin and retains color better than other fabrics. As you can see, hemp fabric is quite practical. It literally prevents you from getting stinky, gets softer with more use, and is stronger and longer lasting than cotton.

### Process for Making Hemp from Clothing Fibers:

1. It is first cultivated or grown.
2. Harvested.
3. Retted or the process whereby naturally occurring bacteria and fungi, or chemicals, break down pectin that bind the hemp fibers to be released. Common techniques consist of soaking in water or laying on the ground and letting dew do the retting.
4. Fibers broken apart.
5. Scotched or beating the stems, which separates the desired fibers from the hemp's woody core.
6. Hackled or combing the stems to remove unwanted particles.
7. Roving made or aligning the fibers with each other, which improves strength.
8. Spun into yarn, either wet or dry spun, then made into cloth.



### Activities to Do:

Now that you have learned about new fibers used to make clothing and interior design products, take it to the next step:

1. Choose one of the above fibers and research more about it and create a poster or other presentation and share. You will be surprised how many people are not aware of these new fibers.
2. Search the internet to find and buy a garment made from one of these fibers and wear it, enjoying the qualities described above. Be sure to let others know what you are wearing!

Activity created by Sue Byrd, PhD, Professor Emeritus, University of Tennessee at Martin.  
Elements of this activity were adapted from Kansas 4-H Leaders Manual, Textiles: Concepts and Principles, All Things Bio: Making Clothes from Milk, Textiles Learner: New Corn Fibers, Fabric Link: Manufactured Fiber, and The Sustainable Fashion Collective: Hemp Fibre Fabric Eco Benefit

## STEM ACTIVITY 9: The Science Behind Fabric Finishes

### Understanding Textiles (Fabric)

#### STEM concepts you will learn:

1. The chemistry behind fabric finishes.
2. Technology used to apply finishes to fabric.



#### Clothing and Textiles Project

**Outcome:** Select an appropriate functional finish on fabric based on intended use.

**Indicator:** Experiments/activities completed.

#### Performance objectives:

Student will **know** the special functional finishes, their purposes, and why and how they work. Student will be able **to select** the appropriate functional finish on fabric of garments based on intended use.

As you know, there are many steps between harvesting (or producing) a fiber and the resulting piece of fabric or garment. Many processes are necessary to turn fibers into finished products. From spinning fibers to making yarns, to weaving, knitting, dyeing, cutting and sewing, all of these are steps most fibers undergo to be transformed into apparel you purchase. Another important step you may not be aware of is applying finishes to fiber, yarns, fabric or garments so they will perform as intended. This activity focuses on the process of **finishing fabric**.



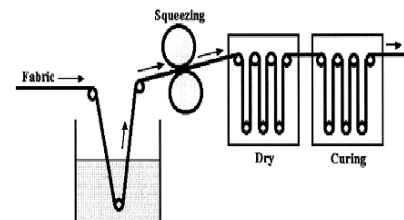
**First let's define the term finishing.** Finishing is a process performed on fibers, yarns or textiles (fabric) that changes the:

- Appearance.
- Feel.
- Performance, such as making the final product permanent press, water repellent or flame retardant.

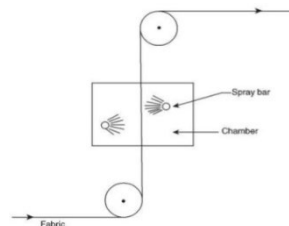
Finishing can be done during the fiber, yarn or fabric manufacturing or may be done by “converters.” Converters are separate companies that finish yarn or fabric according to a garment manufacturer’s needs and can also perform standard finishing applications and then sell fabric to the garment manufacturers.

Finishes are applied to fabric using various technology and techniques. Here are the most common ways finishes are applied:

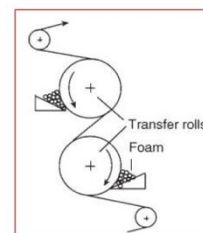
1. **Water bath application.** In this technique the fabric passes through a water solution that contains the chemical finishing substance.



2. **Spray finishing.** In this technique, the fabric is held tight over rollers and passed through a chamber where the specific finish is applied using a spray system.



3. **Foam finishing.** This method uses foam that contains the chemical finishing solution. The foam is applied by the fabric passing through rollers with blades.



In this activity, we will concentrate on functional finishes, which are finishes that affect the actual performance or enhance the use of a garment.

### Shape Retention Finishes



These are very popular finishes because they decrease the amount of ironing that is required by reducing the wrinkling of a fabric.

The chemistry behind wrinkles in fabrics:

Wrinkles are caused by crushing fabrics during wear and washing. This allows the molecules in the fibers to break and bond with other molecules to form wrinkles. A substance called a “resin” was discovered and when added to fabric makes it wrinkle resistant. It works by forming a bond between molecules to

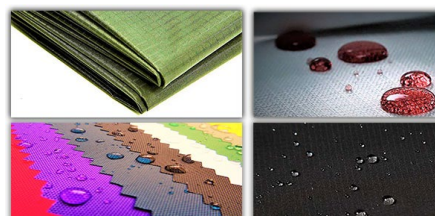
remind them to return to their proper place.

Think of resin as an elastic glue. “Wrinkle resistant” fabrics contain 3 percent resin. “Wash and Wear” fabrics contain 7 percent resin, allowing these fabrics to be washed and rinsed but requiring removal before spinning and drying. “Durable Press” or “Permanent Press” contain 10 percent resin and retain their shape and pressed appearance after repeated washings, wearings and tumble dryings. This method is the most popular finish for cotton/polyester blends and must be used on fibers that contain some cotton.

**Water Repellency** finish makes the fabric resistant to getting wet — but with enough force, water will penetrate the fabric. The degree of repellency depends upon:

- A. How the finish is applied. It can be added at different stages in the production process.
- B. How soiled is the garment? The more soiled, the less repellent.
- C. The fabric construction. This is actually a better guide to the repellency than the finish. The tighter the weave and finer the yarns the more repellent the fabric will be when treated.

Many carpets are treated with a product called Scotchgard, which serves to repel water and oil-based products to keep your carpet fibers from absorbing water or oil which in turn will cause stains. This product can also be used on shoes and fabric used outside to help the product become water repellent.



Synthetic fabrics, such as nylon and polyester, tend to be naturally water repellent. These fibers are often used for rain wear and umbrellas. They may still be treated for extra protection.



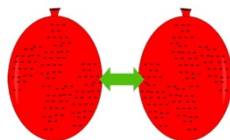
**Antistatic Finish.** Have you ever had clothes stick to you or after you take off an item over your head, your hair sticks up in the air? That is called *static cling*. It is caused when there is buildup of electrons on the fabric and usually happens in synthetic fabrics, such as nylon and polyester unless they are treated. It tends to be more apparent when the atmosphere is dry.



Antistatic finishes function to improve removal of electric buildup from fibers in one or more of these ways:

- A. They improve surface conductivity so excess electrons move to the atmosphere.
- B. They attract water molecules, thus increasing fiber conductivity.
- C. They develop a charge opposite that on the fiber, neutralizing it.

Most of these finishes are not durable and must be replaced during care. Fabric softeners function in a similar manner and help as an antistatic finish. These finishes are widely used on carpet fibers.



**Flame Retardant Finishes**, as the name of this finish implies, protect the fabric (and person wearing a garment made from this fabric) from initial flames of a fire.

The chemistry behind how this happens:

These finishes work by blocking one leg of the fire triangle (fuel, ignition, oxygen).

This finish can be used on cotton, rayon, nylon and polyester. They must be durable (withstand 50 washings), nontoxic and noncarcinogenic, as well as exhibit no odor or change in hand (feel) of the fabric. For the most part they are not visible, yet they increase the cost of the item. “Flame-resistant” finishes are more expensive and more resistant to flame than the “retardant” finishes.



The degree of flame retardancy is determined by:

- A. How flame resistant the fibers are themselves;
- B. Using substances that have been made resistant by adding retardants to the spinning solution when making synthetic fibers; and
- C. Application of retardant finishes.

Flame-retardant finishes are required by law to be applied to fabric intended for children’s sleepwear unless the fabric is naturally flame retardant. That is why when you go to a fabric store to buy fabric such as flannel typically used for sleepwear, you will see a notice on the bolt of fabric related to its suitability for use in sleepwear.

**Soil and Stain Release.** This finish functions by repelling soil or preventing a chemical bond between the soil and fabric. The use of this finish makes fabrics easier to clean. It is applied to the surface and will wash away after 20 to 30 washings. The higher the resin content (as in durable press) the more tendency the fabric has to attract oil stains. To aide in stain removal, use spot cleaners to attack oily stains.



## Taking it to the Next Step: Experiments for 4-H'ers and Project Groups

### The Science Behind Fabric Finishes Hands-On Experiment #1 — Why Are My Clothes Wrinkled?

**Goal:**

Experience how fabrics wrinkle

**Supplies:** 3-inch square of 100 percent cotton muslin

Note: You can do this experiment by taking clothing with these different fiber contents and wad up the corner of the garment to test wrinkability.

**What to do:**

1. Take a 3-inch square of 100 percent cotton muslin and wad it in your hand.
2. Hold fabric for 30 seconds.
3. Release the fabric and put it on a table surface without smoothing out.
4. Let the fabric “rest” for one minute.
5. Then observe the wrinkles, rating the level of wrinkles on a 1 to 5 scale with 1 = very few wrinkles and 5 = a high level of wrinkles.
6. Record your findings in the chart below. Now perform the same experiment on a 3-inch piece of cotton/polyester blend fabric.
7. Repeat the experiment with a 100 percent polyester square.

**Observations**

Fabric	Wrinkle Level (rating scale 1, 2, 3, 4, 5)
100 percent Cotton 3-inch Square	
Cotton/Polyester 3-inch Square	
100 percent Polyester 3-inch Square	

Describe the differences in the three samples as a result of your experiment:

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If you have a garment that you want to have a less wrinkled and crisper look, you can add your own temporary finish.

**Try this:** Take two 7-inch squares of 100 percent muslin fabric. Using spray starch, follow the instructions on the label, and apply the spray to one of the squares. Iron as directed. After the fabric swatch is cool, feel the fabric and describe below. Now feel the fabric square that you did not spray and record your observation.

Description  
(Examples: stiff/limp; rough/soft)

Square treated with starch	
Square not treated	

What can you conclude from the above experiment?

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## The Science Behind Fabric Finishes

### Hands-On Experiment #2 — Why Are My Clothes Still Wet?

**Goal:**

Understand how static electricity is formed with fabrics.

**Supplies needed:** Two balloons, polyester or nylon cloth, wall.

**What to do:**

1. Inflate two balloons.
2. Charge one of the balloons by rubbing a polyester or nylon cloth against it.
3. Place the charged side of the balloon against a wall.
4. Try pressing the balloon against different surfaces to see if it sticks. The balloon may need a second charge.
5. Try pressing the charged balloon against a second balloon.
6. Now charge both balloons by rubbing them against the cloth.
7. Make a hypothesis.

**Experiment A:**

1. Take two pieces of 100 percent cotton muslin cut to 7 inches by 7 inches.
2. Spray one of the pieces with Scotchgard. Let dry.  
Note: You can dry with a hair dryer.
3. Take a spray bottle of water and lightly spritz one side of the untreated muslin sample holding it vertically (with the nozzle set at a wide fine spray).  
Note: The water absorbency of the fabric.
4. Repeat the same process with the Scotchgard treated fabric swatch.
5. Note the difference below.

**Experiment B:**

1. Take a 7-inch square of nylon, one of polyester, and one of 100 percent cotton.
2. Lightly spritz one side of each fabric and note the water absorbency of each.
3. Hang each piece to dry and note when the nylon and polyester samples dry as opposed to the cotton sample.  
Note: You can use a hair dryer to speed up the process.

Fabric Sample	Water Absorbency (High, Medium, Low)	
Muslin — untreated		
Muslin treated with Scotchgard		
	Water Absorbency (High, Medium, Low)	Drying Time (Rank dryness as 1 <sup>st</sup> , 2 <sup>nd</sup> , or 3 <sup>rd</sup> )
Nylon		
Polyester		
Cotton		

From these experiments what have you learned?

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## The Science Behind Fabric Finishes

### Hands-On Experiment #3 – Why Is My Hair Standing Up?

**Goal:**

Understand how static electricity is formed with fabrics.

**Supplies:** balloons (2), polyester or nylon cloth, wall

**What to do:**

1. Inflate two balloons.
2. Charge one of the balloons by rubbing a polyester or nylon cloth against it.
3. Place the charged side of the balloon against a wall.
4. Try pressing the balloon against different surfaces to see if it sticks. The balloon may need a second charge.
5. Try pressing the charged balloon against a second balloon.
6. Now charge both balloons by rubbing them against the cloth.
7. Make a hypothesis.

What happened when the charged side of the balloon was placed against a wall?

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What happened when the balloons were pressed against one another?

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Was your hypothesis correct? If not, how would you change your experiment?

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**What's Going On?**

By rubbing the balloon with a piece of fabric gives it a *negative charge*, also known as static electricity. Enough static electricity will force the balloon to stick to neutrally charged surfaces, such as walls, by attracting the positive charge to the surface. The balloon is light, so this charge is enough to cause it to stick to the wall.

If you try to leave the balloon on the wall, eventually it will fall to the ground. In this case, the static charge dissipates over time, causing the balloon to lose its negative charge and unstick itself.

The two balloons will stick together if one is charged in the same way the balloon sticks to the wall. However, two negatively charged balloons will repel each other.

Activity created by Sue Byrd, PhD, Professor Emeritus, University of Tennessee at Martin.  
Elements of this activity were adapted from Kansas 4-H Leaders Manual, *Chemical Finishing of Textiles* from Askum University, and [textilemates.com/manufacturing-flame-resistant](http://textilemates.com/manufacturing-flame-resistant).

## STEM ACTIVITY 10: Smart Apparel Products to Meet the Needs and Desires of Today's and Tomorrow's Consumer

### Understanding Textiles (Fabric)

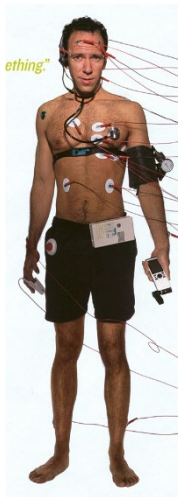

#### STEM concept you will learn:

The technology and equipment used to make various clothing for monitoring the body, exercising and entertainment purposes.

#### Clothing and Textiles Project

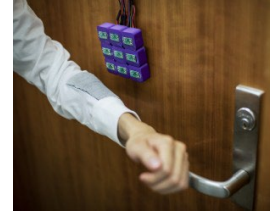
**Outcome:** Analyze the cost and use of Smart garments by today's youth for convenience in technology.

**Indicator:** Completion of one of the activities.

Then	Now
<p data-bbox="381 808 633 840">Ex: The Smart Shirt</p> <p data-bbox="203 861 795 1039">Monitors vital signs, such as heart rate, respiration and body temperature. This is worn by law enforcement, astronauts, military personnel, firefighters, the chronically ill, elderly who live alone, athletes and infants.</p> 	<p data-bbox="974 808 1274 840">Example: A Smart Shoe</p> <p data-bbox="820 861 1412 997">Adidas 1 — Uses a magnet sensor, microprocessor and cable system to continuously adjust the shoe's cushioning while your run.</p> <p data-bbox="820 1018 1412 1249">Nike Free 5.0 — Comes close to running barefoot with precise snugness that is modified via Nike's Adapt app or the buttons in the midsole. This would allow a basketball player to relax the fit "during a time out," then tighten around their foot when the game resumes.</p> 

Today's technology is "stepping" up to give us clothing and accessories that help monitor our vital signs, create better performance in sports, and make life easier. It can also be fun to wear clothing with light-up technology and clothes that change color, those that are camouflaged. In this lesson, you will learn about all of these options.

**Open Your Door with Your Clothes** — Soon you will be able to embellish your clothes with enough data to open your door. Researchers have created passcode-storing clothes made with thread that contains silver or copper. Normally, the magnetic poles of atoms in those metallic threads are pointed in random directions. By holding a magnet close to the thread, all poles align in a single section of cloth to point either north or south. Those magnetic orientations encode a bit of data (1 or 0), which an instrument called a magnetometer can read. It provides the code needed to unlock your door.

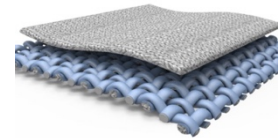


### Technology Connected to Your Clothing



Clothes of the future are here now and integrate electronics, such as phones, so we can listen to music, get directions and take phone calls by touching a button or brushing a sleeve.

Researchers at the Georgia Institute of Technology (Georgia Tech) have created energy-harvesting yarns that can be woven into washable textiles. They work by taking advantage of static electricity that builds up between two different materials thanks to friction. Sewn into socks, sweaters and other clothes, the fabric can harvest enough energy from the motion of waving your arms to power a sensory that could one day charge your cellphone.



Heart-sensing fabrics have sensors knitted into the fabric with a transmitter on the front. The transmitter transmits data to a watch.



### Clothes that Change Colors



For several years, textiles (especially T-shirts) that change color either by heat (from the body) or sunlight have been available. But how does this happen and what is the difference?

- I. **Heat-sensitive shirts** use thermochromic dyes and respond solely to heat, not light. Thermochromic dyes are temperature-sensitive compounds that temporarily change color with exposure to heat. These dyes or inks are either in crystal or liquid form when used to create the design.
- II. **Sun or light-sensitive shirts** use photochromic dyes and respond solely to sunlight/ultraviolet (UV) light, not heat. Photochromatic or photochromism is described as a reversible change of color upon exposure to light. When you go indoors and out of the UV light, a different chemical reaction takes place. The absence of the UV radiation causes the molecules to return to their original shape, resulting in the loss of their light-absorbing properties.

Now let's look at a different technology where you can control the color of your shirt! Color-changing clothes are on their way. Designers have experimented with embedding LEDs and e-Ink screens in clothing and accessories with varying levels of success.



The College of Optics and Photonics at the University of Central Florida has announced the first user-controlled color-changing fabric, which enables the wearer to change its color using a smartphone.





Here's how it works:

1. Each thread woven into chromophous fabric incorporates within it a thin metal micro-wire.
2. An electric current flows through the micro-wires, slightly raising the thread's temperature.
3. Special pigments embedded in the thread respond to this change of temperature by changing their color.
4. Users can control both when the color change happens and what pattern will appear on the fabric using an app.
5. For example, a solid purple tote bag now has the ability to gradually add blue stripes when you press a "stripe" button on your smartphone or computer.



### New Technology So You Can Blend in with Your Background

## Optical Camouflage: How to Disappear

It's not really an "invisibility suit." University of Tokyo's Susumu Tachi wanted to show how retro-reflective materials, which reflect light back toward the source, can create the illusion of seeing through objects. His setup of cameras and projectors might one day be used to hide ugly walls, allow pilots to see the ground and help surgeons see a patient's insides.

**HOW IT WORKS:**

- 1 **VIDEO CAMERA** captures images from behind the subject
- 2 **SUBJECT** wears a suit covered with retro-reflective fabric
- 3 **COMPUTER** processes the captured image and sends it to the projector
- 4 **OBSERVER** wearing head-mounted projector sees the background clearly

**WHAT THE OBSERVER SEES:**

**PROJECTOR OFF**

**PROJECTOR ON**

**RETRO-REFLECTIVE MATERIAL**

Light enters  
Light exits in same direction

**THE FABRIC:** Retro-reflective material makes the visible invisible

SOURCES: SUSUMU TACHI LABORATORY, GRADUATE SCHOOL OF INFORMATION SCIENCE AND TECHNOLOGY, UNIVERSITY OF TOKYO; 3M CORP.

GRAPHIC BY GUILBERT GATES—NEWSWEEK



**Activities to Do:**

Now that you have learned about new fabrics with technology incorporated into them, take it to the next step:

1. Research one of the smart clothes ideas in this lesson.
2. Explore on the internet how to make your own light-up (LED) clothing and try it out.
3. Meet your younger 4-H'ers and teach them what you have learned.
4. Create a poster or PowerPoint with this information and share with others.
5. Interact with a person who has used a new technology in clothing.

Activity created by Sue Byrd, PhD, Professor Emeritus, University of Tennessee at Martin.  
Elements of this activity were adapted from Desol Manufacturing Company, Futurity: Magnetized Fabric that Store Data  
([futurity.org/magnetized-fabric-stores-data-1591452](http://futurity.org/magnetized-fabric-stores-data-1591452)),

## STEM ACTIVITY 11: Know Your Sewing Machine and How It Works

### Creating Clothing and Accessories

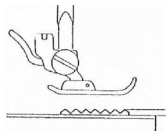
#### STEM concepts you will learn:

1. The technology of the parts of a sewing machine and how they make the sewing machine work.
2. The engineering of making two-dimensional fabric into a three-dimensional item.
3. The math involved in using exact measurements to create/sew an item.

#### Clothing and Textiles Project

**Outcome:** Identify the parts of the sewing machine.

**Indicator:** Using sewing machine to create a sewn project.



Operating the sewing machine may seem awkward at first, but with a little help, patience and practice, you will soon be sewing. Let's get acquainted with the parts of the sewing machine, so you will have a fun experience. All machines are not alike, but they do have the same basic parts, usually located in the same place on the machine.

#### Parts of the Sewing Machine:

**Balance (hand) wheel** — moves the needle up and down as it turns. Can be moved by hand to move needle out of fabric.

**Bobbin** — holds the thread for the underside of the seam. Bobbins are located in different positions on various machines and are held in place by a bobbin case within a bobbin compartment.

**Bobbin winder** — Holds the bobbin while thread is wound from the spool onto the bobbin.

**Feed dog** — small teeth or bars go up and down to move your fabric as you sew.

**Foot pedal** — controls how fast or slow the machine sews. It's like the gas pedal on a car.

**Needle** — carries the top thread and goes up and down through your fabric to make stitches.

**Presser foot** — holds your fabric in place as you sew.

**Pressure bar lever (lifter)** — raises and lowers the presser foot.

**Reverse stitch lever** — used to sew a backstitch at the beginning and end of stitching a seam to lock the stitch in place.

**Spool pin** — holds the spool of thread in place while you sew.

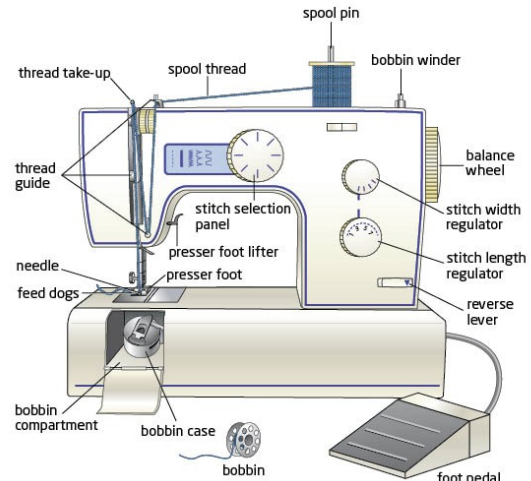
**Stitch length regulator** — used to change the stitch length for regular sewing or basting.

**Stitch selection panel** — used to select specific decorative and/or functional stitches.

**Stitch width regulator** — determines the width of the stitch, usually used for zigzag stitches.

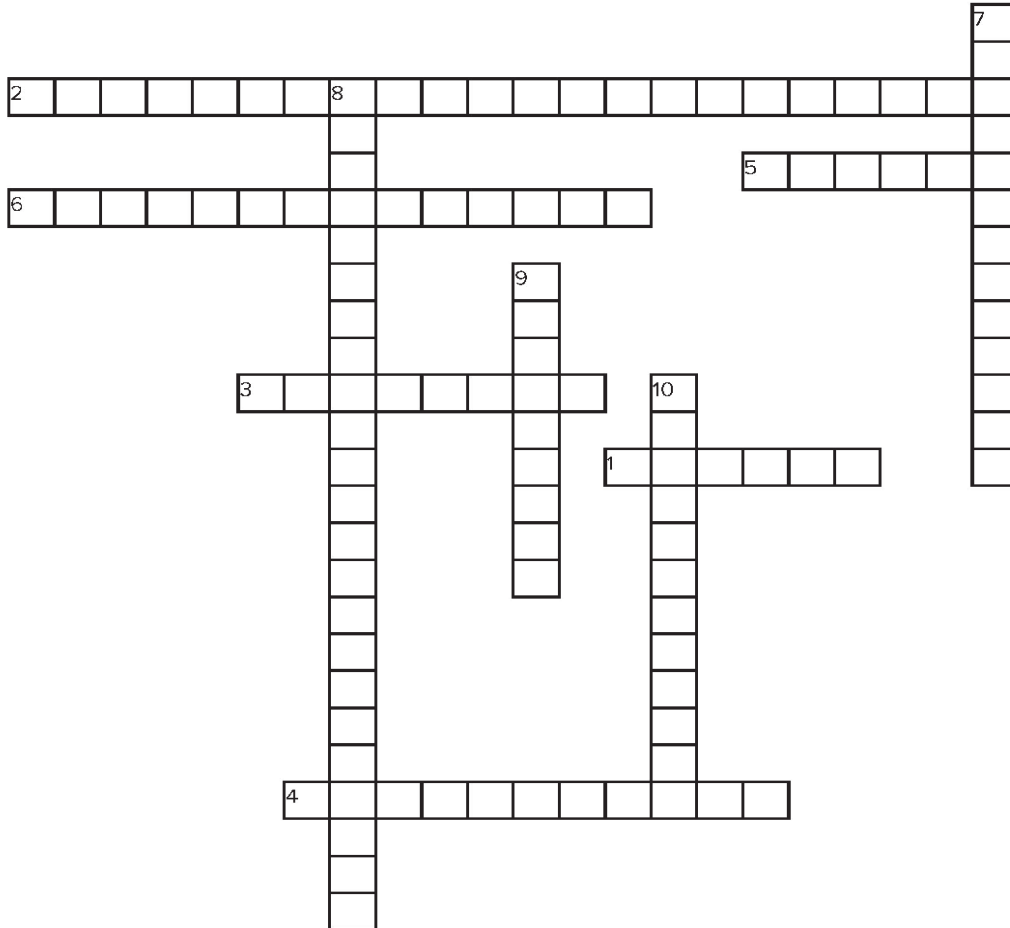
**Thread guides** — guide the thread along the machine to hold it in place.

**Thread take up lever** — moves up and down as the stitch is formed and keeps thread at the adjusted tension. Always have this lever at the highest point when you stop sewing.



## Know Your Sewing Machine Crossword

Now that you have learned about the parts of the sewing machine and their functions, test your knowledge with this crossword puzzle. Note: Allow a space between words for multiple word answers.



### Across

- 1 Watch out, I am sharp.  
Change me to get a zigzag stitch.
- 2 The presser foot and I work as a team to grip and move fabric through the machine.
- 3 We have to do this to stop the stitches from undoing.
- 4 I hold the bottom thread.
- 5 Always have this at the top when you start and when you stop.

### Down

- 7 Turn this to get the needle to its highest point.
- 8 This control makes the stitches short or long.
- 9 Place the spool of thread onto me.
- 10 I keep the fabric in place while you sew.

Answers to Crossword Puzzle—

Across: 1. Needle 2. Stitch selection panel 3. Feed dog 4. Back stitch 5. Bobbin 6. Thread take-up

Down: 7. Balance wheel 8. Stitch length regulator 9. Spool pin 10. Presser foot

Now that you have learned about the parts of the sewing machine, let's look at how the machine actually works in order to be able to start sewing.

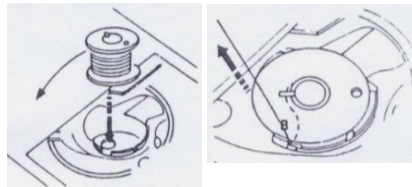
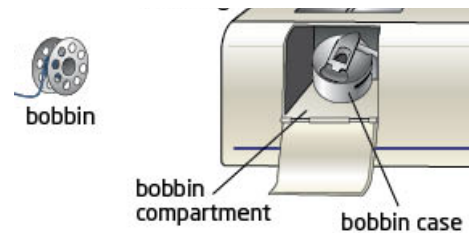
As you look at various sewing machines you may think they all look very different. However, most are more alike than different. They work by taking two threads and knotting them together through fabric. This looping action forms the stitches that hold the fabric together. All sewing machines use two threads. One is the bottom thread or "bobbin" thread, and the other is the top thread. When you first start sewing, you may get your 4-H leader, project leader or parent to thread the sewing machine, but the sooner you learn to thread the machine yourself, the easier it will be for you to sew with little supervision.

### Threading the Machine

Looking at the image to the right, you can see an illustration of how the upper thread of the sewing machine is threaded. You will want to use the instruction book from your machine to determine the exact threading sequence. You may also want to look on the internet for a short video that will show you how to thread your machine. All instructions will have basic steps in common.

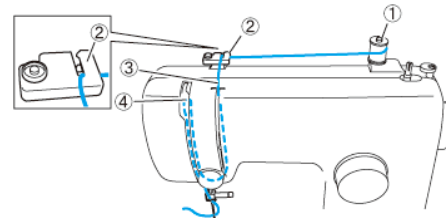
### Threading the Bobbin

All sewing machines have a bobbin. A bobbin (image to the right) will be placed in a bobbin case.



In older sewing machines, the bobbin case may be a separate metal case made so that once the bobbin is placed in, it will be inserted into the base of the machine.

In newer machines, the bobbin will drop into the base of the machine from the top (in front of the needle). It is important that the thread within the bobbin is slipped through a slit in the bobbin case to position it in place.



### Beginning to Sew

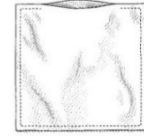
Next, you will get a chance to "drive" the sewing machine. It is important that you "drive" the sewing machine just as someone learns to drive a car. Begin slowly and watch where you are going. As you operate the machine, don't do anything else, no TV or other distractions. You will want to practice sewing on paper first to get used to it. As you sew, whether clothing, accessories or home decorating items, there are two key steps to success.

1. **Securing your stitches:** In order for your stitches to be secure and not ravel out, you need to do a backup stitch at the beginning and end of sewing. In order to do this, you will need to locate the backup/reverse lever on your machine. It is usually on the right side of the machine. (See the illustration to the right.) To secure your stitches, first start sewing about 1/2 inch along your seam, hold down the reverse lever, and stitch backwards going within 1/8 inch of where you started. Release the lever and continue to sew. When you get to the end of sewing, slow down and sew to within 1/4 inch of the



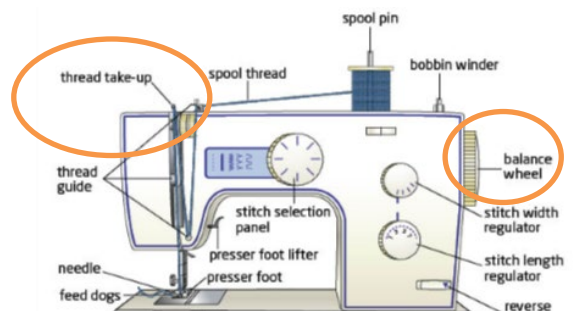
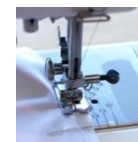
end. Then again hold down the reverse lever and sew backward about 1/2 inch. Release the lever and sew to the end.

2. **Turning corners while sewing:** Many items you will sew will include corners, such as pillows and scarves. To turn a corner while sewing, begin your sewing and as you approach a corner, slow down. When you get right to the corner, use the big wheel on the right end of the machine called the balance wheel, turning it toward you until the needle is on your fabric. Now lift up the presser foot and rotate the fabric at a right angle, put the presser foot down, and continue sewing. You can see on the square below an example of sewing a square pillow where corners will need to be turned.



More tips for success:

- Always make sure the presser foot is down against the fabric before beginning to sew.
- Always make sure the thread take-up lever is in the up position (image to the right) at the top of the sewing machine before beginning to sew. If it is not there, use the balance wheel and turn it toward you while holding onto the thread end that is coming out of the needle.



- Before cutting the thread after you have sewn a seam, be sure the thread take-up lever is at the top of the sewing machine. If not, use the instructions in step 4 above to move it.
- Always make sure the fabric is about 1/8 inch from the edge of the end when beginning to sew. You must be able to see the fabric under the needle. This will prevent the thread from knotting up and create a neat flat seam.

# Practicing Your Sewing (Practice Sheet)

In order to be comfortable with sewing, you need to practice, practice and practice! So, before you take your first stitches on fabric, follow the instructions below and use this paper to sew on.

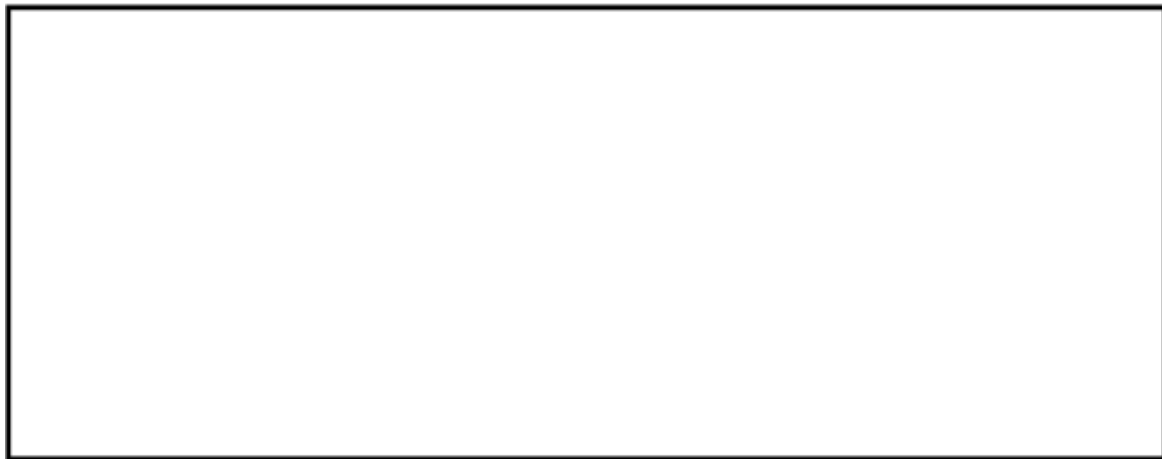
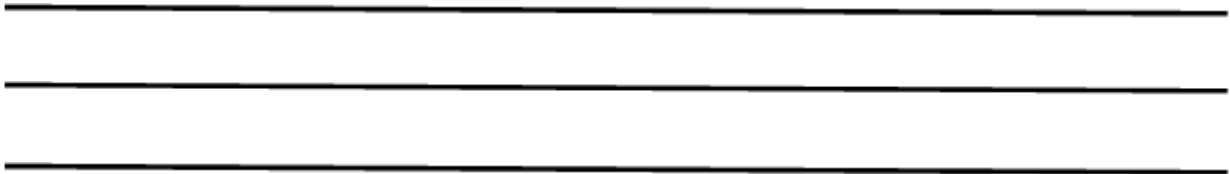
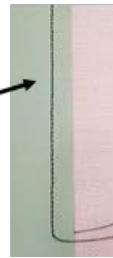
Practice control of your sewing machine by sewing on these straight lines.

1. To do so, slip the paper underneath the presser foot and line up the needle with the end of the line. You can lower the needle onto the paper by using the balance wheel on the right end of your machine, turning it toward you.
2. Lower your presser foot and press on the machine's foot control slowly.
3. Guide the paper to keep the stitches straight by laying your hands on top of the paper (not too close to the needle) and moving the paper slightly without pressing down too hard. When you get close to the end of the line, go a little slower.
4. When you stop, be sure that the thread take-up lever at the top left of the sewing machine is in the up position. If not, turn the balance wheel toward you until it is at the top.
5. Pull the paper to your left (it should slide out easily) and cut your threads about 2 inches from the needle.

After you have sewn on a few of the lines and have fairly straight stitches, try sewing a few lines, **securing your stitches** at the beginning and end of each line. Use the instructions on the previous page to do this.

Practice **turning corners** on the rectangle below, using the instructions on the previous page. Now that you have learned to sew following a line, let's take it one step further.

Many times when sewing accessories, decorative and craft items, **the seams will be 1/4-inch wide**. To practice this, take this piece of paper and line the edge of one side with the inside edge of the presser foot. Begin sewing, keeping the edge of the paper aligned with the inside edge of the presser foot. This will create a stitching line that is 1/4 inch from the edge. Do this on all sides.



# Taking it to the Next Step: Experiments for 4-H'ers and Project Groups

## Know Your Sewing Machine and How It Works Hands-On Experiment #1 — Let's Make a Square Decorative Pillow

Decorative pillows are the perfect way to add a personal touch to any room. In this experiment, you will learn to select fabric suitable for making a pillow and the color and design that matches your room décor. You will also learn to sew straight lines and turn corners on the machine as well as hand-sewing techniques.



### Goals:

1. Design and create a decorative pillow.
2. Test skills learned on how to use a sewing machine.

**Supplies you will need:** woven fabric, matching thread, sewing scissors or shears, polyester fiberfill or a pillow form, sewing machine, hand-sewing needle, water soluble marking pen

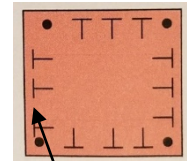
Note: The amount of needed fabric depends on the size of the pillow (Example: If making a 14-inch pillow, you'd buy 1/2 yard of fabric).

### What you need to do:

1. Select your fabric and filling (or pillow form) for your pillow.  
TIP: Remember, when selecting fabric to select a medium-weight woven fabric that is either solid or has a design that you like. Cotton/polyester blends work well. Stay away from designs that are stripes, which are more difficult for a first project.

2. Cut two squares of fabric that are 1/4 inch bigger on each side than your finished pillow measurement. (Example: If you want to make a 14-inch pillow, cut 14 1/2-inch squares, which allow for a 1/4-inch seam allowance on each side.)

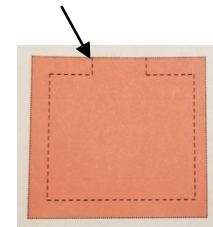
3. Place the two squares so they are on top of each other, and so the brighter side of each square faces the other square's brighter side. This is called putting the right sides together. Pin around the edges to hold fabric in place. Mark each corner 1/4 inch from the edge to make it easier when sewing.



4. Now, you are ready for the fun part. Begin sewing on one side about a third of the way from a corner, beginning at the edge as shown in the diagram below (see pin arrow). Do a backstitch at the beginning and end of sewing to lock the stitch in place. Sew around three sides of the fabric squares, using a 1/4-inch seam allowance. Be sure to take the pins out before sewing over them.

A seam allowance is the measurement from the edge of the fabric where you want the sewing machine to stitch the fabric.

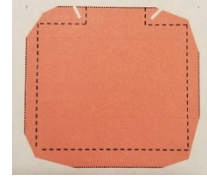
5. Make sure that when you get to the corners to put your needle on the fabric, lift up the presser foot (the machine part that is holding the fabric in place), turn the pillow so you can continue stitching down the next side, put the presser foot down, and continue sewing.
6. On the fourth side of the squares, sew a third of the way in from that corner then turn and stitch to the edge of the fabric as shown. This leaves you an open space in the middle of that side.
7. Trim the corners as shown in diagram to eliminate bulk when turning the pillow right-side out. Be





careful not to cut through your sewing. Also clip in at the area where you began your stitching as shown in the diagram.

8. Use the space that is left open to turn your pillow right-side out. Use closed scissors and put them to the inside of your pillow and push the corners out so they make nice points.
9. Finally, you are ready to finish your pillow. Stuff it firmly with polyester fiberfill or your pillow form.
10. Handstitch the opening closed, folding in the raw edges. Enjoy!



Activity created by Sue Byrd, PhD, Professor Emeritus, University of Tennessee at Martin.  
Elements of this activity were adapted from Kansas 4-H Leaders Manual

## STEM ACTIVITY 12: The Nitty Gritty of Stains

### Caring for your Clothes

#### STEM concepts you will learn:

1. The chemistry behind why stains appear on your clothing.
2. The science behind treatments that will remove stains.

#### Clothing and Textiles Project

**Outcomes:** Discover what happens to fabric to cause a stain when spills take place. Select and use proper techniques for removing stains from clothing.

**Indicator:** Completion of experiment.



Have you ever spilled something on your clothes that caused a stain? Most of us have. Learning the science behind stains will help you discover how to remove them.

#### How a Stain Becomes a Stain

Stains come from many sources. Most of them result from spilling food on our clothing. Different foods create stains of different colors and different strengths.

**Stains** are a result of a chemical reaction between the staining substance and the fabric. They primarily form when a substance is spilled onto a surface and the molecules are trapped inside the fibers and pores of the fabric. The spilled substance coats the underlying material and the newly formed stain reflects back light of its own color, which is how the stain becomes visible to the naked eye. It's the same concept of how we see color. Every wavelength of light is absorbed except the color you see. For example, if you spill mustard on your shirt, all the colors in the spectrum of visible light but yellow are absorbed. So, you see the yellow mustard stain.



#### How does the kind of fabric that something is spilled on make a difference?

Water swells **natural fibers**, such as cotton and wool, but not polyester or acrylic, which are **manufactured fibers**. So, a water-based stain will go deeper into a natural fiber unless a special hydrophobic or water-repellent finish has been recently applied. Polyester or acrylic, in contrast, will repel water-based stains but absorb oily ones unless a special finish has been fixed on those fibers.

#### Types of Stains

There are two fundamental types of stains: 1) those that are water-based and 2) those that are oil-based. Here are some common stains and how they are classified.

- a) **Water-based stains:** coffee or tea, ketchup, cola, fruit juices, jelly, milk, blood and ink
- b) **Oil-based stains:** margarine or butter, chocolate, cooking oil, mayonnaise, salad dressings, peanut butter, deodorant, makeup, and a ring around the neck of a collared shirt

## Removing Stains

Stains can be a challenge to remove. How much of a challenge depends on:

1. The chemical nature of the fiber (in the clothing),
2. The food spilled, and
3. The length of time the stain has set (the longer the stain has been on a garment, the harder it is to remove).

The standard advice for removing stains is to follow the “three P’s of stain removal” — promptness, patience and perseverance. Using the correct cleaning product may help in reducing your frustration in removing stains.

Stain removal requires strong products, such as cleaning enzymes, bleach or specialty solvents.

- I. **Cleaning enzymes** are included in some detergents and presoak products. They break stains into simpler forms that can then be attacked by detergents.
- II. **Cholorine and oxygen bleaches** whiten, brighten and loosen soils from fabrics. They break the connection between the stain and the fiber or they make the stain colorless through oxidation. Oxygen bleach is added to some detergents and is also sold as a separate product. Chlorine bleach is not added to detergent but is sold separately. All bleaches can damage fabric, so be sure to follow directions on the bleach and product labels.

### General Tips to Follow:

1. The earlier you start to treat any stain the better.
2. Always remove any excess of the stain substance by blotting (never rubbing) the area with clean water (an ice cube works in a pinch) or running it under cool water.
3. Try carrying a stain stick or wipe in your purse or car so you always have a way to immediately pretreat a stain if you can’t get to work on removal immediately.
4. Remember that you should never put the garment in the dryer until you’re sure the stain is out. The heat of the dryer could cause the stain to set and become permanent.

You will find many guides on the internet that address how to remove specific stains.

## Taking it to the Next Step: Experiments for 4-H'ers and Project Groups

### The Nitty Gritty of Stains Hands-On Experiment #1 — Experimenting with Stains

Now that you have learned the science behind stains, try this experiment. Have fun! Use the attached worksheet **before, during and after** the experiment.

#### Goal:

Experience removing stains created on washable fabrics.

**Supplies needed:** newspaper or plastic to protect surface, permanent pen/marker, 100 percent cotton fabric, cotton tip swabs, two 1-gallon plastic bags, detergent without enzymes and bleach, detergent with enzymes and bleach, plastic spoon, hot water, dishpan of cool water, paper towels, ketchup, mustard, grape juice and soy sauce

- a) Note: Arm & Hammer or Ivory Snow are detergents without enzymes or bleach. Tide with bleach is a detergent with enzymes and bleach.
- b) TIP: Be sure to read the labels of the detergents ahead of time so you will use the correct ones for this experiment.

#### What to do:

1. Answer the before questions on the provided worksheet.
2. Cut two pieces of cotton fabric into 6 inch by 6 inch squares.
3. Label both pieces of the fabric, as shown to the right.
4. Label one of the 1-gallon plastic bags E & B to represent “enzyme and bleach” solution.
5. Using a cotton swab, apply a small amount of ketchup to each fabric sample on the K square, making a stain a little larger than a quarter. Be sure to rub ketchup into area.
6. Repeat with mustard, grape juice and soy sauce.
7. Let fabric set at least five minutes while you go to the next step.
8. Prepare the plastic bags that would simulate a “washing machine” by placing about 1 teaspoon of a detergent that contains cleaning enzymes and oxygen bleach (such as Tide with bleach) in the bag marked E & B.
9. In an unlabeled plastic bag place 1 teaspoon of a detergent that does not contain enzymes or bleach (such as Arm & Hammer or Ivory Snow).
10. Add **hot tap water** to fill one detergent bag about one-quarter full. Place one of the stained fabrics in the bag. Push out the excess air while closing the bag. Set aside and repeat with second bag.
11. Check that the bag seals are secure. Squeeze, roll or shake the bags gently for five minutes to simulate a washing machine. Keep the bags over your work area.
12. Open one bag and remove the fabric sample. Pour the detergent water into the sink.
13. Spread out the empty bag and lay a paper towel on top of it.
14. Rinse the fabric in a dishpan of cool water. Spread the fabric on the paper towel on the plastic bag to dry. The empty bag under the towel reminds you which detergent was used. You may change the paper towel a couple of times to get as much moisture out of the fabric as possible.
15. Repeat steps 8-14 with the second bag and fabric sample.
16. Record your results on your Worksheet.

K	G
M	S

# Stain Removal Experiment Worksheet

**Before starting the experiment, answer the following questions.**

1. Create a hypothesis. What do you think will happen to the stains when using detergent with no enzymes or bleach? Hypothesis:
2. Create a hypothesis: What do you think will happen to the stains when using detergent with enzymes or bleach? Hypothesis:
3. What do enzymes do to stains?
4. What does bleach do to stains?

**During the experiment answer the following questions:**

1. How does the water change as you agitate the bag?
2. How are the stains changing as you agitate the bag?

**After the experiment answer the following questions:**

1. What happened in general to the stains after five minutes of agitation?
2. Which stains were more difficult to remove?
3. Which detergent is better for removing stains?

4. Would using cold water make a difference in the stain removal? If you think so, why?
  
5. What would happen if you didn't agitate the bag?
  
6. Would the stains be harder to remove the longer the stain is on a garment? Why or why not?
  
7. What is one thing you have learned from this experiment that you will use?

Activity created by Sue Byrd, PhD, Professor Emeritus, University of Tennessee at Martin. Elements of this activity were adapted from *In-Touch Science: Food & Fabrics* by Cornell Cooperative Extension, Smithsonian Museum Conservation Institute, [sterlingcleaner.com/chemistry-stain-removal](http://sterlingcleaner.com/chemistry-stain-removal) and The American Cleaning Institute (ACI) [cleaninginstitute.org/cleaning-tips/clothes/stain-removal-guide](http://cleaninginstitute.org/cleaning-tips/clothes/stain-removal-guide).

## STEM ACTIVITY 13: What's in that Detergent?

### Caring for your Clothes

#### STEM concepts you will learn:

1. The types of energy needed to clean clothes.
2. The chemistry behind how detergent components work.
3. The science behind the effects of types of water on the use of detergents to clean.



#### Clothing and Textiles Project

**Outcomes:** Identify the different ingredients in laundry detergent, their purposes and how your clothes get clean.

**Indicator:** Completion of experiment.



When washing your clothes, have you ever wondered how detergents actually get them clean? You may have noticed that your detergent has different ingredients and sometimes different colors. There are different components of detergents that help the cleaning take place.

#### How Your Clothes Get Clean

When clothes are dirty and need to be cleaned, energy is needed to make it happen. There are three different types of energy required:

1. **Chemical Energy** — The laundry detergent provides chemical energy. The composition of the detergent and the way the ingredients interact with the dirt and stains in your clothing make the cleaning process happen. What actually happens is that molecules in the detergent (that are so small you can't see them) attract stains and help pull the dirt away from your clothing.
2. **Mechanical Energy** — The mashing machine provides mechanical energy by moving the clothes back and forth and rubbing them together. This rubbing action helps loosen the dirt from the surface of your clothes. When clothes need hand-washing, you actually provide the mechanical energy by using your hands to rub together the clothing.
3. **Thermal Energy** — Warm or hot water provides the thermal energy needed to clean clothes. Warm or hot water helps the stain or dirt dissolve quicker. When clothing needs to be washing in cold water, detergents have to work harder for the clothes to get clean.





**Activities to Do:**

Now that you have learned about what's in the detergents you use to clean your clothes and how they work, take it to the next step:

1. Complete the experiment that follows. Be sure to take pictures of yourself in action for your portfolio.
2. Research more about one of the following: the chemistry behind how enzymes work; the effects of using petrochemical-based detergent on the environment; and how soap was made in the mid-1900s.
3. Create a poster about what you have learned to exhibit at your club or a fair.

## Taking it to the Next Step: Experiments for 4-H'ers and Project Groups

### What's in that Detergent?

#### Hands-On Experiment #1 — Testing the Difference in Natural and Synthetic Detergents

Now that you have learned the science behind how detergents work, it's time to do an experiment.

#### Goal:

Experience stain cleaning to understand detergent effectiveness.

**Supplies Needed:** newspapers or plastic to protect surface, bath towel, permanent pen/marker, 100 percent cotton muslin fabric, two 1-quart plastic containers, plant-based (natural) detergent, petrochemical-based detergent, warm water, substances to stain fabric.

- a) NOTE: Be sure to read the labels of the detergents ahead of time so you will use the correct ones for this experiment.
- b) TIP: Mrs. Meyer's Laundry Detergent or Charlie's Soap are examples of plant-based or natural detergents. Tide and Cheer are examples of petrochemical-based detergents. Stain options might be ketchup, butter, orange juice, mustard, dirt or makeup.

#### What to do:

1. Complete the worksheet creating your hypotheses of what you predict will happen during the experiment.
2. Cut eight pieces of cotton muslin fabric into 6 inch by 6 inch squares.
3. Find four different sources of stains around the house.  
Examples: ketchup, butter, orange juice, makeup foundation or soil (dirt) from outside.
4. Separate fabric into four stacks. Apply to each piece in the stack one of the substances you collected to stain the fabric. Let this dry naturally or by using a blow dryer. Write on the edge of each fabric with permanent marker the substance you have applied.
5. Prepare solutions in two 1-quart containers as follows: In each put  $\frac{3}{4}$  quart of warm water and 1 tablespoon of detergent (plant-based in one and petrochemical-based in the other). Mark the lids of the containers to indicate the detergent used in each.
6. To begin your experiment, take two of the samples with the same stain on them, placing one in one container and the other in the second container. Secure the lids and shake the containers for three minutes to simulate a washing machine.
7. Open one container and remove the fabric sample. Pour the detergent into the sink. Rinse this sample under warm water for about one minute. Lay this piece out on a bath towel or similar substance, marking which detergent solution was used for later comparison.
8. Repeat the procedure (#7) for the second sample with the same stain.
9. Now follow procedures #5-7 for each of the stain samples.
10. Pat the samples with a cloth until they are reasonably dry.
11. Complete the worksheet with your findings and draw conclusions for your experiment.

## Testing the Difference in Natural and Synthetic Detergents Worksheet

### Before starting the experiment answer the following questions:

1. Create a hypothesis — Will there be a difference in the cleaning of stains with plant-based (eco-friendly) detergent versus petrochemical-based detergent? Hypothesis:
2. Create a hypothesis: Will there be a specific stain that is harder to get out with both detergents? Hypothesis:
3. Check the label of your detergents. Are there enzymes listed in the ingredients for each? If so, which ones?
4. Is bleach listed as an item in either of these detergents? (It is better to use detergents without bleach for these experiments.)

### After the experiment answer the following questions:

1. List Stain used: \_\_\_\_\_  
Which detergent cleaned better? \_\_\_\_\_ Plant-based (eco-friendly) detergent  
\_\_\_\_\_ Petrochemical-based detergent
2. List Stain used: \_\_\_\_\_  
Which detergent cleaned better? \_\_\_\_\_ Plant-based (eco-friendly) detergent  
\_\_\_\_\_ Petrochemical-based detergent
3. List Stain used: \_\_\_\_\_  
Which detergent cleaned better? \_\_\_\_\_ Plant-based (eco-friendly) detergent  
\_\_\_\_\_ Petrochemical-based detergent
4. List Stain used: \_\_\_\_\_  
Which detergent cleaned better? \_\_\_\_\_ Plant-based (eco-friendly) detergent  
\_\_\_\_\_ Petrochemical-based detergent
5. Overall, which detergent is better for removing stains? \_\_\_\_\_ Plant-based (eco-friendly) detergent  
\_\_\_\_\_ Petrochemical-based detergent
6. Which stains were more difficult to remove?

**To think about after the experiment:**

1. What would happen if you didn't shake the container? Why or why not?
2. Would the stains be harder to remove the longer the stain is on a garment? Why or why not?
3. Would you consider using only the eco-friendly detergent? Why or why not?
4. What is one thing you have learned from this experiment that you will use?

Activity created by Sue Byrd, Professor Emeritus, University of Tennessee at Martin.  
Elements of this activity were adapted from the Cleaning Institute.

## STEM ACTIVITY 14: To Make or Buy Your Clothes?

### Creating Clothing and Accessories

#### STEM concepts you will learn:

1. Using math skills to calculate the cost of making a garment.
2. Economic decisions related to buying ready-to-wear instead of sewing.
3. Understanding clothing investment buying.



#### Clothing and Textiles Project

**Outcomes:** Calculate the actual cost of making and buying a garment. Determine the pros and cons of making vs. buying a garment.

**Indicator:** Completion of worksheets.



**To buy or sew your clothes?** There are many things to consider when answering this question. When you go shopping and buy clothes, you may not realize that the actual cost of a garment is more than the price you pay for the garment. You have to consider the cost of keeping that garment clean and wearable over the life of the garment. Of course, the cost of sewing your garment includes the cost of the fabric and notions, but it also includes the cost of your time as well as the cost of cleaning your garment.

During this activity you will learn what to consider and how to make this decision. First of all, let's look at some considerations when deciding to buy or make your clothes:

1. What financial resources do you have available? What is your clothing buying budget?
  - a. Budgets can be stretched surprisingly thin by looking at all available resources. Between 50-75 percent can be saved by successfully sewing garments.
2. What supplies do you have available to you? Do you have a sewing machine and supplies for sewing?
  - a. You may have a relative or neighbor who has the resources that you can use if you don't have them at home.
3. What are your sewing skills?
  - a. If you are a beginning sewer, you may be limited in what you can make. But if you have a passion for sewing, join a project group and increase your skills. If you decide to make your own clothes, be sure not to tackle a sewing design beyond your skills. And, always finish what you start!
4. How much time do you have available to make a garment?
  - a. It takes time to sew clothing. It is a great hobby and can be very satisfying, but make sure you have that extra time.

## Sewing vs. Buying

Let's look a little deeper into the advantages and disadvantages of sewing versus buying your clothes:

	Sewing	Buying
Fit of Your garment	You can make your clothes fit so that they are not too tight or loose nor too long or short.	Sometimes you can't find garments that fit you just right. Sometimes you will need to alter them after they are bought.
Obtaining Unique Fashion Looks	You can create a one-of-a-kind look and have unique fashions.	You will see there are often lots of the same garment, which means you see someone wearing the same garment that you have just bought.
Time Involved	Depending on the type of garment you are making, it takes a lot of time to sew a garment. Today's patterns are often made easy and quick-to-sew.	Shopping for and buying clothes usually takes less time than sewing; especially with online shopping, the process is even faster.
Cost of Your Clothes	The cost of fabric and notions for sewing vary. Most fabric stores offer discounts and sales, which can make this cost fairly low. Generally, making clothes that you will wear multiple times is less expensive than buying them.	The cost of store-bought clothes varies, but are typically more than those sewn. With fast fashion (inexpensive clothes that you wear for one season), the cost of clothing has decreased.

### Calculating the Costs

As you think about sewing, consider a modified cost-per-wearing formula to calculate how a home-sewn garment would compare to a ready-made one. The cost of your garment includes the price of all supplies, such as fabric, notions, and patterns, the value you place on your time, and the cost of care.

#### Example:

##### Dress, sewn —

###### a) Supplies

- fabric (1 ½ yards of cotton/polyester fabric) at \$8/yard = \$12
- notions – zipper and thread = \$5.50
- pattern = \$6.99
- time (8 hours at \$5/hour) = \$40
- care\* (\$0.35/washing and drying with one wash/dry per week for 20 weeks) = \$7

Total Cost = \$71.49

Total Wearings = 20 (once a week for four months)

Total Cost per Wearing = \$3.58 (\$71.49/20)



**NOTE:** Most of the time when we sew, we do it for many of the reasons you learned about, such as 1) we want a good fit, 2) we want a unique look, and 3) we enjoy creating something...it's a hobby. So, we don't take into consideration our time. If you were sewing for someone else, you would want to make sure to include the cost of your time. So, if we recalculate the above without counting our time, the total cost would be \$31.29, and the cost per wearing would be \$1.58 (\$31.29/20).

### **Dress, bought —**

#### a) Supplies

- No supplies, but remember that a bought garment may not be a perfect fit and may not be unique to what others have.

- care\* (\$0.35/washing and drying with 1 wash/dry per week for 20 weeks) = \$7

Dress Cost = \$40.50

Total Cost = \$47.50

Total Wearings = 20 (once a week for 4 months)

Total Cost per Wearing = \$2.38 (\$47.50/20)

\* Cost of Care: Cost of Care assumes 1 load of laundry with approximately 6 clothing items per load = about \$2.10, which includes costs of water, detergent, fabric softener, electricity, equipment, etc.

If you count the cost of your time in sewing, the bought garment costs less per wear, but if you do not count your time, the sewn garment is less expensive.

Your skill level and the value you place on your time are important factors in deciding whether sewing can save money for you. For some, the dollar value of the time involved is less important. A productive use of the time involved may be the most important factor. Many consider sewing a hobby or tension-relieving activity.

The best clothing plan is a balancing act between value and cost. Use the cost-per-wearing formula and your wardrobe plan to keep your wardrobe versatile and efficient.

### **Tips to Make the Clothes You Sew or Buy Last Longer Through Investment Dressing**

When you spend time and money on your clothes, whether buying them or making them, there are ways to stretch the value of your time and money. This can happen through “investment dressing.” You may have heard of this. This is the process of investing more resources toward a particular item or items of clothing that you think will last for a long time. So, how do you figure out what to buy that fits into investment dressing?

1. Be sure you explore and have an understanding of fashion styles, trends, your personalities and what fashion styles look good on you based on the lines, colors and shapes.
2. Do an inventory of what you have in your closet and what pieces are missing. Consider buying or making items that are classics (clothing items that will be popular for many years). Classic pieces include straight skirts, dress slacks, button-up solid colored shirts, blazers, cardigan sweaters, a little black dress, navy blue jeans and zip-up fleece jackets.
3. When shopping for fabric, keep these classics in mind related to color and style, and look for high-quality fabrics.



**Activities to Do:**

Now that you have learned how to calculate the cost of what you make and buy, use the cost-per-wearing formula using a piece of clothing in your closet and a garment you are making or would like to make.

**Cost Per Wearing of Sewn Garment**

Supplies	Price per Unit	Quantity	Total Supply Cost
Fabric			
Buttons/Zippers			
Other notions			
Thread			
Pattern			
<b>Total</b>			
<b>Time</b>		\$5	
	Total Hours	Price per Hour	Total Cost of Time
<b>Care</b>	\$0.35		
	Price per Wash/Dry	Total Washings/Dryings	Total Cost of Care

Total Cost (Total for supplies + time + care) = \_\_\_\_\_

Total Wearings = \_\_\_\_\_

Total Cost per Wearing (Total Cost/Total Wearings) = \_\_\_\_\_

NOTE: You should also figure this, deleting the value of your time spent sewing.

Total Cost per Wearing Deleting \$ for Time Spent Sewing (Total Cost/Total Wearings) = \_\_\_\_\_

**Cost Per Wearing Bought Garment**

Garment Name:	Price	Quantity	Total Costs
Garment		1	
Care	\$0.35		
	Price per Wash/Dry	Total Washings/Dryings	Total Cost of Care

Total Cost (Total for garment cost + care) = \_\_\_\_\_

Total Wearings = \_\_\_\_\_

Total Cost per Wearing (Total Cost/Total Wearings) = \_\_\_\_\_

Activity created by Sue Byrd, PhD, Professor Emeritus, University of Tennessee at Martin. Elements of this activity were adapted from Kansas 4-H Clothing Leaders Notebook and Cost of Care from [thesimpledollar.com/save-money/a-cost-comparison-of-home-laundry-and-laundromats](http://thesimpledollar.com/save-money/a-cost-comparison-of-home-laundry-and-laundromats) and [purewash.com/blog/the-cost-of-doing-laundry](http://purewash.com/blog/the-cost-of-doing-laundry).



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