# Whacky Armor

Leader Guide

Style Engineers

Fashion through science

WITH THIS ACTIVITY

- Handout (Optional)

MODULE


## Big Picture

Viscoelastic polymers are soft and somewhat fluid at rest. Some, like gloop or silly putty, will harden temporarily when struck with force. This behavior, called 'shear-thickening', makes them ideal for use in impact protective padding—we call it *Whacky Armor!*

## What's the goal?

Young designers make and test a shear-thickening viscoelastic polymer to show that such materials can provide impact protection, are lightweight, and can conform to the body.

## Grouping

The whole group acts out the introductory exercise, but individuals make their own *Whacky Armor*.

## Materials

**What they need: (per person)**

- 2 cups for mixing
- 5 Tbsp. Elmer's Glue — multipurpose glue
- 6 Tbsp. warm water
- Food coloring (optional)
- 1 Tbsp. 20 Mule Team™ Borax (laundry section of grocery store)
- Stir sticks or plastic spoons
- Surface for kneading (cover tables in plastic or wax paper)
- Safety glasses
- Small wrapped hard candies
- Press'n Seal® wrap, 2 pieces 12" long
- Resealable plastic bag

**Supplies to Share**

- Markers
- Measuring cups and spoons
- 5 pound kettlebell weights
- Ruler, minimum 12"
- Scissors

**Prep Time: 45 Minutes**
**Activity Time: 45 Minutes**
**Difficulty: Level 2**

# Let's get started!

Before we make our viscoelastic polymer using glue and borax, let's demonstrate how it works.

Locate an open space and divide the group into two teams — 3/4 of the designers will be "glue" and 1/4 will be "borax."

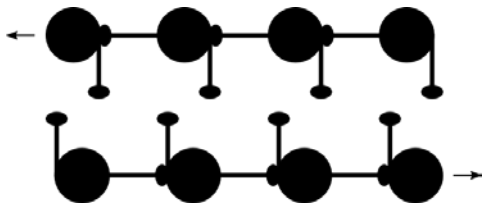
1. Ask the glue team to form two facing lines about 6 ft. apart. Each individual represents a monomer of vinyl acetate.

**VOCABULARY**
**Monomer:** a single chemical unit. The monomer in glue is vinyl acetate.

2. Glue team members place their right hands on the left shoulders of the persons to their right. This action links the monomers to form a polymer.

**VOCABULARY**
**Polymer:** monomers linked together to form long chains. In glue, vinyl acetate monomers form chains of polyvinyl acetate, a single chemical unit.

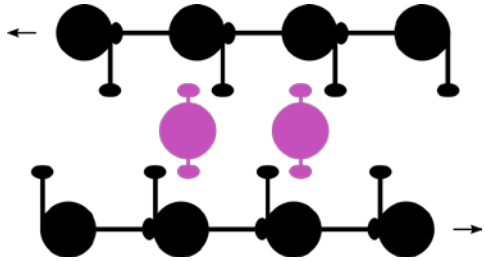
3. Glue team members extend their left arms straight toward the opposite line. The left hand represents functional chemical groups that can bond with other reactive groups. Flap those reactive hands!



**VOCABULARY**
**Functional Group:** a group of atoms capable of bonding with other functional groups. In *Whacky Armor,* the borate ions of the borax react with the polyvinyl acetate in the glue.

4. The two lines of glue maintain their “polymer positions” as they take six sidesteps to the right and then six sidesteps to the left repeatedly. Their extended left hands SHOULD NOT TOUCH because the glue remains fluid—it easily slides back and forth.

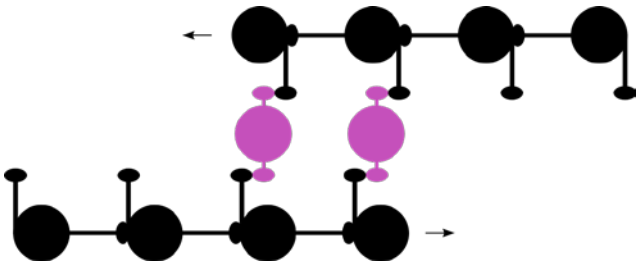
5. Ask the “borax” representatives to place themselves randomly between the two lines of glue. They should hold both arms outstretched from their sides—one arm extended toward each line of glue.



6. Ask the glue lines to take six sidesteps to the right and then six sidesteps to the left as in Step 6, but this time they “high five” the outstretched hands of the borax units. Taking time to touch hands slows the movement of the glue, demonstrating the cross-links, short-lived linkages that occur when the glue-borax mixture thickens.

**VOCABULARY**
**Cross-linking:** the formation of a chemical bond between two molecules.

7. Finally, ask the glue lines to take six sidesteps to the right and then six sidesteps to the left as in Steps 6 and 8. After a few steps the leader will shout WHACK (the sound of stress or pressure being applied—the sound of a weight striking the polymer). This is the signal for the glue and borax to link forearms in a strong grip that stops movement. The borax units should be linked to both lines of glue. Shout RELEASE and everyone drops hands.



8. Repeat step 8 until everyone understands that when stress is applied, the cross-linking bonds cause the viscoelastic polymer (glue-borax) to harden (undergo shear thickening). When the stress is removed, the polymer returns to a more liquid state.

**VOCABULARY**
**Shear thickening:** the behavior of a material that thickens and hardens when shear stress (such as hitting) is applied, but returns to its more fluid state with time or when the stress is removed.

# Make Whacky Armor

1. Label two cups: #1 (Glue) and #2 (Borax).
2. Place 5 Tbsp. glue and 4 Tbsp. water into cup #1 and mix well.
3. Add a few drops of food coloring (optional).
4. In cup #2 dissolve 1 Tbsp. of borax in 2 Tbsp. warm water.
5. Pour the borax solution into the glue and water while stirring. Watch the way the two solutions interact while you count to ten. You are making a colloid. Stir until completely mixed to a putty-like consistency.

**VOCABULARY**
**Colloid:** molecules of one substance dispersed in a second substance. The dispersed particles do not settle, but remain in suspension.

6. Pour the material onto a table covered in plastic wrap or wax paper, and knead until smooth. You've made Whacky Armor, a viscoelastic polymer with interesting viscosity properties!

**VOCABULARY**
**Viscoelastic polymer:** a material that exhibits both deforms and stretches when stressed by actions such as squeezing, stirring, or hitting.
**Viscosity:** a fluid's resistance to flow. Water flows more easily than glue so glue has a higher viscosity than water.

7. Play with your *Whacky Armor* and observe how it behaves under these conditions (Optional: record your observations on your handout.)

   -Shape it into a ball. Can it bounce?
   -Slowly poke your finger into the ball. What do you observe?
   -Squeeze the ball. How does it feel?
   -Lay the ball on the table and quickly tap it with the flat part of your hand. What happens?
   -Leave the ball untouched on the table and count to ten. Does it keep its shape?
   -Roll the putty into a rope about 6” long. Can you wrap it around your finger?
   -Pull the two ends. Does it stretch? Does it break?

8. Put on safety glasses.

9. Take wrapped hard candy and place it on the floor (ideally on a newspaper or other covering). Ask a partner to hold a ruler vertically next to your candy. Drop the 5 lb. kettlebell weight from a height of 12 inches, or the top of the ruler, onto the candy. Did the candy break or is it still intact?

10. Prepare a second piece of candy and lay it on the floor. Cover it with your *Whacky Armor*. Drop the 5 lb. kettlebell weight from a height of 12 inches as in Step 9. What happened? Did the candy break? Is the polymer still flexible? Do you think that Whacky Armor could protect your joints when playing sports?

11. Flatten your *Whacky Armor* to about half an inch. Seal it between two pieces of Press’n Seal® wrap, leaving wide margins so you can use it in the Knee Drop n’ Spin activity. You may also store the polymer in a resealable bag.

# Wrap it up

1. Discuss and compare observations from Step 7. Can you think of ways to use these unusual characteristics?

2. Discuss your observations in Steps 9-10. Explain how dropping a weight on the candy relates to the introductory “glue and borax” demonstration.
3. What are the advantages of using a viscoelastic polymer with shear-thickening properties for protective sports equipment rather than a hard shell?
    A. Answer: It is light in weight and is flexible enough to conform to the body.
4. Can you think of other fluids that act the same way as the viscoelastic polymer that you made?
    A. Answer: Quicksand is the made-for-movies example. The more the victim thrashes about the thicker the quicksand becomes and the harder it is to escape. If the victim relaxes, he/she will float because the body is less dense than the quicksand.
    B. Answer: The synovial fluids in your elbow and knee joints become harder and stronger when mechanical stress is applied. They relax and become more liquid when the stress is removed. Thus, your usually flexible knees will resist impact (to some degree) when you fall while playing soccer.
5. Can I purchase protective gear that uses shear-thickening technology?
    *A.* Answer: Yes, both sports and military equipment use shock-absorbing materials with shear-thickening behavior. In the 2006 Winter Olympics, the US and Canadian ski teams made history with their “soft armor.” Vests, kneepads, elbow pads, shorts, pants and gloves are widely available.

# Take it Further

Ask young designers to start dropping the kettle bell on a candy from a height of one inch and increase incrementally by 1" until the candy breaks. Repeat with *Whacky Armor*-protected candy until they identify the drop height at which 5 pounds breaks the candy despite the protection. This process demonstrates scientific method. If the experiment is repeated and recorded two to three times, they can calculate the average breaking point (the sum of all the trial breaking points divided by the number of trials). For more information, search the Internet and read more about about shear-thickening fluids, soft armor, liquid body armor, Armourgel®, D30®, Deflexion® and Poron®,