Activity Guide

Choreography of Matter: Designing Playful Polymers

Design your own tactile polymer by experimenting with a range of materials, exploring their physical and chemical properties.

Grade Level: Suitable for Kindergarten and up

Suggested Time: 3 hrs

Overview

Students will create their own synthetic polymer using everyday household materials including school glue and laundry booster (e.g.: Borax) in this activity. They will investigate chemical transformation that enables the creation of gooey, stretchy, or bouncy polymer.

This activity can serve as a pathway to learn about polymer science in fun and playful ways, looking into physical and chemical reactions as part of the polymer making process. The activity can also foster entrepreneurial learning and design thinking. Students will improvise and develop their own unique versions of pleasurable and purposeful DIY polymer products, and iterate on initial designs.

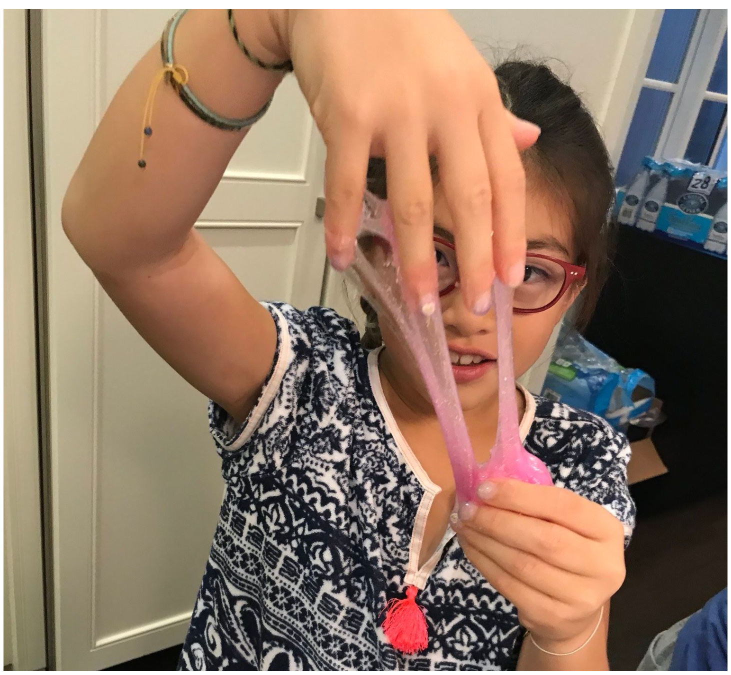


Fig1: “making slime". 18 August 2017. Online image. Flikr. 1 August 2019. https://www.flickr.com/photos/jennycu/36494061122/in/photostream/

Learning Goals

By completing this activity, students will:

- Make a polymer toy (Slime) using liquid polymer (PVA Glue) and Borax solution.
- Investigate physical and chemical properties of the synthetic polymer toy
- Create a polymer recipe by experimenting with different amounts of glue, Borax solution, and additional materials to attain desirable color, texture, viscosity, interactivity, and opacity.
- Enhance the value of their product with branding and promotional methods such as
    - Designing a logo and packaging
    - Conducting user testing to seek feedback on their polymer.
    - Making a commercial advertisement to promote their product.
- Reflect on their design process by addressing challenges and learning opportunities.

Key Concepts

- Polymers
- Viscosity
- Opacity
- Shear-thickening fluids
- Acid
- Base

Materials and Resources

Personalized Protective Equipment	Basic Polymer	For Material Iterations
• Lab coats • Safety Goggles • Gloves • Hair ties for long hair	• Non-toxic Washable School Glue • Borax Laundry Detergent Booster • Water • Disposable Cups (to mix from large containers if necessary) • Measuring cups and spoons set • Clear Plastic Storage Bags • Stirrers	• Food coloring • Styrofoam balls • Fishbowl beads • Glitter • Shaving Creams • Clear glue • Essential oils
For Branding and Product Promotion • Storage Jars • White stick-on round labels • Color pens and markers • Poster Paper • Scissors	**For material testing** • Baking Soda • Vinegar • Flashlight • Digital scale • Rulers • Disposable Cups	**Materials for Advanced Exploration** ***Optional for Elementary, needed for higher grades** • Thermochromic Pigment • Photochromic Pigment • Magnetic Powder • Spirulina powder • Corn Starch • Glow in the Dark Paint • Shampoo • Liquid Starch

Safety Tips

Students should have the agency to experiment on their own, but the teachers must supervise them at all times. Following are the steps that students need to follow as part of the safety measures while doing a scientific exploration.

- Do not eat or drink any materials used in this activity. Keep the materials away from your mouth, nose, and eyes!

- Wear protective gear, including a lab coat, safety goggles, and gloves before starting the activity. Tie back long hair
- Read all warning labels on all materials being used.
- Be sure to clean up and dispose of materials properly when you are finished with the activity.
- Wash your hands thoroughly after playing with your polymer toy

*Adapted from Chemical and Laboratory Safety Guidelines by the American Chemical Society
https://www.acs.org/content/acs/en/chemical-safety/resources.html

Preparation

- **Example Projects:** We recommend that teachers create at least two versions of the polymer toy with packaging in advance and share it with the students to spark their interest.
- **Space Setup:** Keep the personalized protective equipment ready for students before they begin the experiment. Teachers could set up supplies for basic slime recipe per table and set up a separate common table for extra supplies for advanced exploration.

Process

You can refer to the following steps while guiding students through this exploration. We encourage students to work in teams, but they can work individually.

Section A: Making the Synthetic Polymer

Students can begin this exploration by getting hands-on and making the polymer. This will allow them to be familiar with the key ingredients and get comfortable with the process. They will also feel confident that they can make their own slime in simple and accessible ways. Following are the steps to make the slime:

Students will need the following materials for this section:

- 1 Cup Water + 1 tbsp Water
- 1 tbsp Borax
- 1 tbsp glue
- Ziplock Bag (1 per student)
- 1-2 drops of food color
- Disposable Cup (1 per student)
- Measuring Spoon (1 set for 4 students)
- Stirrer (1 per student)

Step1

Make Borax Solution: Add 1 tbsp of Borax with 1 cup of water. Stir it till it dissolves.
*Teachers can make the borax solution in advance

Step 2

Mix Glue with Water: Put 1 tbsp of glue and 1 tbsp of water in a ziplock bag. Seal the bag and mix the components by squeezing the bag. Students may choose to add a few drops of food color to the mix if they prefer.

Step 3

Add Borax: Open the bag and add 1 tbsp of borax solution. Seal the bag again.

Step 4

Knead the Polymer: Squeeze the bag to knead the polymer. You would feel the texture changing as you press it. When the texture stops changing, your polymer would be ready.

Step 5

Play with the polymer toy: Take the polymer out of the bag and play with it.

Section B: Analyzing the properties of the polymer.

Students can now continue playing with their polymer wearing an investigator's hat. They can Observe, record and analyze the physical and chemical properties of their polymer toy.

Encourage students to record their observations using the following table. They can use these to test their polymer:

- Ruler
- Weighing Scale
- Flashlight
- Vinegar
- Baking Soda
- Disposable Cups
- Measuring cups

Color What is the color of your polymer?	**Texture** How does it feel?	**Opacity** When you pass the light through it does it go through the polymer?
Bounciness Roll the polymer into a ball and drop it and record. ● How high does it bounce? ● How many times does it bounce until it comes to rest?	**Mass, Volume and density** ● Pour the polymer into a measuring cup until it takes the shape of the container. How much is the volume? ● Put the polymer on a weighing scale and measure the mass in grams. ● Can you measure the Density of the polymer using its mass and volume? ● Is there another way to measure the density of the polymer?	**Stretchability** Stretch the polymer blob and measure how far does it stretch?
Adhesion Affix your polymer to a flat vertical surface. ● How long does it stick to the surface before gravity affects it?		
Viscosity Roll the polymer into a ball and place it into a flat surface and measure: ● How long does it take for the ball to become flat disc? ● What is the diameter of the disc?	**Chemical Reaction with Acid** What happens when you add vinegar (acetic acid) to your polymer?	**Chemical Reaction with Base** What happens when you add baking soda (sodium bicarbonate) to your polymer?

Cycle 1

*Teachers could prompt the students that there shouldn't be more than 3 tbsp of total ingredients in the bag.

For eg. students could mix 1tbsp glue and 1 tbsp water to the ziplock bag and then add 1tbsp borax solution

For students who are struggling to start the process, teachers could suggest 1 tbsp glue, 1 tbsp water and 1 tbsp borax solution as initial quantity

Ingredients	**Glue**	**Water**	**Borax Solution**	**Total Quantity of Ingredients in the bag**
Initial Quantity				**3 tbsp**
New (Variation)				**3 tbsp**
New (Variation 2)				**3 tbsp**

Record Observations

Texture	
Opacity	
Viscosity	

Cycle 2

Ingredients	Water	Glue	Borax Solution	New Ingredient 1
Initial Quantity				
New (Variation)				
New (Variation 2)				

Record Observations

Texture	
Opacity	
Viscosity	

We encourage students to develop their final, packaged product and create their company identity *as a team*.

Recipe for Final Product-Company Name:

Ingredients	Water	Glue	Borax Solution	Other/final Ingredient
Initial Quantity				
New Quantities				

Record Observations

Texture	
Opacity	
Viscosity	

Section C: Designing the ideal polymer.

Students can switch from the role of an investigator to the role of a designer after exploring the properties of their first polymer model. They can now explore strategies to modify the initial polymer recipe to create the most appealing polymer toy.

Learning Tip: To understand how to design a better polymer, the students will need to know what kind of transformation is actually happening when they make the polymer. Knowing this will help them explore alternative materials and methods that can be used in the polymer design process. You can use this opportunity to introduce the scientific explanation of the polymer making process.

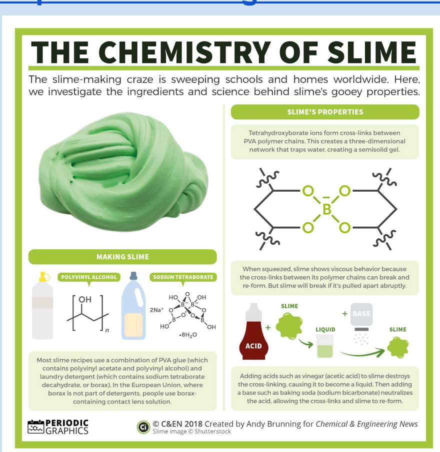
Following are helpful guides that suggests the scientific of polymer

- **The Science of Slime**

https://www.acs.org/content/dam/acsorg/education/resources/highschool/chemmatters/articlesbytopic/solidsliquidsgases/chemmatters-dec2004-slime.pdf

- **The Chemistry of Slime**

https://cen.acs.org/education/Periodic-Graphics-chemistry-slime/96/i25



Designing new models of slime:
Students will design 3 versions or samples (iterations) of polymer and choose the best design. Students can experiment with different ingredients and quantities and create new polymer recipes. You can use the following prompts to guide the students to design a new polymer toy.

- How can you make your polymer toy visually appealing?
- How can you improve the texture of your polymer toy?
- How can you make your polymer smell better?
- How can you make your polymer more bouncy?
- How can you make your polymer more stretchy?
- How can you make your polymer more eco-friendly?

When students have their polymer samples (designs) ready, encourage them to analyze the properties of their designs and compare. (See section B)

Clean-Up: Before moving on to the next section, ask students to clean-up their spaces and get ready for the next phase. They will need the designs of their polymer.

Section C: Starting a Polymer Company

Do you know that a 14 year old girl has her own successful slime business? If you could start a slime company what would you do?

Fig:https://commons.wikimedia.org/wiki/File:Green_and_blue_slime.jpg

Using this prompt, encourage students to create a fake polymer toy company and start preparation to launch their new products.

As part of this, students will need to first strategize who will work in their company and what departments they need to have within their company. One they have figured it out, you can prompt them to explore branding and marketing strategies.

Encourage students to:

- Think of a name for their company
- Design a logo
- Design packaging for their product
- Conduct user testing to improve their product and packaging
- Assess the safety of their product to understand any associated risks. For instance, the users might be tempted to eat a product that resembles frosting and smells like vanilla!
- Design an ad to market their product

Show and Share: Innovators Stage

Encourage students to pitch their products in front of an audience. Create a stage where each team has 2 mins to share their polymer product with others. Students could also use this opportunity to seek feedback about their product from their peers.

Prompts

- What is your product?
- What is unique about your product?
- Who can benefit from using your product?
- What are the ingredients?
- What are your strategies to minimize damage to the environment that may be caused by your product?
- What is the message you want to share with the audience through your product?

Fig: "Borax Slime". 16 April 2017. Online image. Flickr. 2 August 2019. https://www.flickr.com/photos/ptc24/34668214794

Further Polymer Exploration

Students could use the following materials to make different versions of polymers.

- *Food Coloring* to alter the appearance of the polymer
- *Essential oils* to make the polymer smell nice
- *Shaving cream* to make the polymer fluffy
- *Fishbowl Beads* to make the polymer crunchy
- *Glitter* to make the polymer shine
- *Styrofoam balls* to enhance the texture of the polymer
- *Glow in the dark pigments* to make the polymer glow
- *Thermochromic pigments* to make the polymer change color when exposed to heat
- *Photochromic pigments* to make the polymer change color when exposed to sunlight

Additional Resources

- **Magnetic Slime**

https://frugalfun4boys.com/make-magnetic-slime/

- **Eco-Friendly Slime**

https://www.bbc.co.uk/newsround/45563215

- **Slime and Goo Resources from American Chemical Society**

https://www.acs.org/content/acs/en/education/resources/k-8/science-activities/chemicalphysicalchange/slimegoo.html

Alignment to Standards

We think the following standards are most relevant to this activity. You could adapt this list for your class session. The complete list of all the standards can be found on the respective websites of each framework.

NGSS Standards

- Practice 1 Asking Questions and Defining Problems
- Practice 2 Developing and Using Models
- Practice 6 Constructing Explanations and Designing Solutions

Massachusetts Standards for Engineering/Design/Technology

Grade 1:

1.K-2-ETS1-1. Ask questions, make observations, and gather information about a situation people want to change that can be solved by developing or improving an object or tool.*

1.K-2-ETS1-2. Generate multiple solutions to a design problem and make a drawing (plan) to represent one or more of the solutions.*

Grade 2:
2.K-2-ETS1-3. Analyze data from tests of two objects designed to solve the same design problem to compare the strengths and weaknesses of how each object performs.* Clarification Statements: • Data can include observations and be either qualitative or quantitative. •

Grade 3:
3.3-5-ETS1-1. Define a simple design problem that reflects a need or a want. Include criteria for success and constraints on materials, time, or cost that a potential solution must meet.*
3.3-5-ETS1-2. Generate several possible solutions to a given design problem. Compare each solution based on how well each is likely to meet the criteria and constraints of the design problem.*

Grade 4:
4.3-5-ETS1-3. Plan and carry out tests of one or more design features of a given model or prototype in which variables are controlled and failure points are considered to identify which features need to be improved. Apply the results of tests to redesign a model or prototype.*
4.3-5-ETS1-5(MA). Evaluate relevant design features that must be considered in building a model or prototype of a solution to a given design problem.*

Grade 5:
5.3-5-ETS3-1(MA). Use informational text to provide examples of improvements to existing technologies (innovations) and the development of new technologies (inventions). Recognize that technology is any modification of the natural or designed world done to fulfill human needs or wants. 5.3-5-ETS3-2(MA). Use sketches or drawings to show how each part of a product or device relates to other parts in the product or device.*

Grade 6:
6.MS-ETS1-1. Define the criteria and constraints of a design problem with sufficient precision to ensure a successful solution. Include potential impacts on people and the natural environment that may limit possible solutions.*
6.MS-ETS1-5(MA). Create visual representations of solutions to a design problem. Accurately interpret and apply scale and proportion to visual representations.*
6.MS-ETS1-6(MA). Communicate a design solution to an intended user, including design features and limitations of the solution. Clarification Statement: • Examples of intended users can include students, parents, teachers, manufacturing personnel, engineers, and customers.

Grade 7:
7.MS-ETS1-2. Evaluate competing solutions to a given design problem using a decision matrix to determine how well each meets the criteria and constraints of the problem. Use a model of

each solution to evaluate how variations in one or more design features, including size, shape, weight, or cost, may affect the function or effectiveness of the solution.*
7.MS-ETS1-4. Generate and analyze data from iterative testing and modification of a proposed object, tool, or process to optimize the object, tool, or process for its intended purpose.*
7.MS-ETS1-7(MA). Construct a prototype of a solution to a given design problem.*

Grade 8:
8.MS-ETS2-4(MA). Use informational text to illustrate that materials maintain their composition under various kinds of physical processing; however, some material properties may change if a process changes the particulate structure of a material.

ISTE standards:

Innovative Designer
4c Students develop, test and refine prototypes as part of a cyclical design process.
4d Students exhibit a tolerance for ambiguity, perseverance and the capacity to work with open-ended problems.

For more project ideas visit our website at:
http://aceraschool.org

STEAM Synthetic Polymers Rubric Grades K-2
Initial Impression Observed by Teacher

Level of Initiative	I got started right away on my own	Need some scaffolding/supp ort	Needed lots of scaffolding/support

Observable attributes		**Beginning**
I understand the value of safety in a lab environment and am able to use materials in safe and effective ways		
I am open to new ideas and trying new things		
I persevere even when I get stuck.		
I take risks and learn from failed attempts		

Measure/Rating	**4-Advanced**	**3 - Proficient**	**2 - Developing**	**1 - Beginning**
Engineering Process: Questions and Observations	I asked additional questions and made observations, showing critical thinking beyond the task of the process of creating synthetic polymers.	I asked questions and made observations during the process of synthetic polymers creation.	With minimal support, I asked some questions and made some observations during the process of synthetic polymer creation.	I am beginning to ask some questions, and make some observations during the process of synthetic polymer creation.
Engineering Process: Designing/ Analyzing/ Planning	I can plan and carry out tests of one or more design features of a given prototype in which	I can design and plan out my trials for creating synthetic polymer, making changes for	I can design and plan some for my trials for creating synthetic polymer, making changes for	I am beginning to design and plan for my trials for creating synthetic polymer. I am

	variables are controlled and failure points are considered to identify which features need to be improved.	each new trial. I can analyze the prior outcome, to make appropropriate changes.	each new trial. I am beginning to analyze the prior outcome, to make appropropriate changes.	beginning to make changes for each new trial. I am beginning to analyze the prior outcome, to make appropropriate changes.
Engineering Process: Using Materials effectively	I can accurately interpret and apply scale and proportion to redesign a prototype and have a successful solution for synthetic polymer.	I can use the materials appropriately to follow my design/plan to create synthetic polymer.	I can use some of the materials appropriately to follow my design/plan to create synthetic polymer.	I am beginning to use the materials appropriately to follow my design/plan to create synthetic polymer.

STEAM Synthetic Polymers Rubric Grades 3-5

Level of Initiative	I got started right away on my own	Need some scaffolding/support	Need lots of scaffolding/support

Observable attributes		**Beginning**
I understand the value of safety in a lab environment and am able to use materials in safe and effective ways		
I am open to new ideas and trying new things		
I persevere even when I get stuck.		
I take risks and learn from failed attempts		

	4-Advanced	**3 - Proficient**	**2 - Developing**	**1 - Beginning**
Engineering Process: Questions and Observations	I asked additional questions and made effective observations, showing critical thinking beyond the task of the process of creating synthetic polymers.	I asked questions and made effective observations during the process of synthetic polymers creation.	With minimal support, I asked some questions and made some observations during the process of synthetic polymer creation.	I am beginning to ask some questions, and make some observations during the process of synthetic polymer creation.
Engineering Process: Designing/ Analyzing/ Planning	I can define the criteria and constraints of a design problem with a prototype with sufficient precision to	I can plan and carry out tests of one or more design features of a given prototype in which variables are controlled and	I can plan and carry out some testing of one or more design features of a prototype in which variables are	I am beginning to plan and carry out some testing of one or more design features of a prototype in which variables

	ensure a successful solution.	failure points are considered to identify which features need to be improved.	controlled and failure points are considered and can begin to identify which features need to be improved for success.	are controlled and can begin to identify which features need to be improved for success.
Engineering Process: Using Materials effectively	I can accurately interpret and apply scale and proportion to redesign a prototype and have a successful solution for synthetic polymer.	I can apply the results of tests to appropriately redesign a prototype.	I can apply some of the results of tests to begin to appropriately redesign a prototype.	I am beginning to apply the results of tests to appropriately redesign a prototype.

STEAM Synthetic Polymers Rubric
Grades 6-8

Initial Impression

Level of Initiative	I got started right away on my own.	I required some adult scaffolding and support to get started.	I required full adult scaffolding and support to get started.

Observations by the Teacher

Categories		
I understand the value of safety in a lab environment and am able to use materials in safe and effective ways		
I am open to new ideas and trying new things		
I persevere when I get stuck.		
I take risks and learn from unsuccessful attempts		

Measure/Rating	**4-Advanced**	**3 - Proficient**	**2 - Developing**	**1 - Beginning**
Engineering Process: Questions and Observations	I asked additional questions and made effective observations, showing critical thinking beyond the task of the process of creating synthetic polymers.	I asked questions and made effective observations during the process of synthetic polymers creation.	With minimal support, I asked some questions and made some observations during the process of synthetic polymer creation.	I am beginning to ask some questions, and make some observations during the process of synthetic polymer creation.

Engineering Process: Designing/ Analyzing/ Planning	I can define the criteria and constraints of a design problem with a prototype with sufficient precision to ensure a successful solution.	I can generate and analyze data from iterative testing and modification of the synthetic polymer process to optimize polymer for its intended purpose.	I can plan and carry out some testing of one or more design features of a prototype in which variables are controlled and failure points are considered and can begin to identify which features need to be improved for success.	I am beginning to generate and analyze data from testing and modification of the synthetic polymer prototype process to optimize the polymer's success.
Engineering Process: Using Materials effectively	I can accurately interpret and apply scale and proportion to construct and redesign a prototype based on prior failures and have a successful solution for synthetic polymer.	I can construct a prototype of a solution to a given design problem based on the prior failures of the initial prototype.	I can apply the results of tests to appropriately redesign a prototype.	.I am beginning to apply the results to appropriately redesign a prototype.