Polymer Science

(Three 50-minute class sessions)

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SUBJECT/GRADE LEVEL

Subject Area: Physical science / Chemistry / Engineering
Grade Level: Middle school / High school

Materials

(For 30 students, divided into 8-10 groups)
Gloves and safety glasses

- ENGAGE
  - examples of hydrogel and aerogels (ex. Baby diaper, hair gel, toothpaste, wound dressing, contact lenses, aerogel shoe inserts)
  - Small whiteboards and markers for each group, or digital whiteboards
  - Video example of aerogel/hydrogel use
- EXPLORE
  - Digital balances and trays
  - Graduated cylinders
  - Bowls
  - Mixing utensils
  - Water
  - Borax
  - Elmer's school glue (5-ounce bottles)
  - Food coloring
  - Baking soda
  - Colored sand
  - Contact lens multipurpose solution
  - Liquid starch
  - Timer
  - Ruler
- EXPLAIN: Small whiteboards and markers for each group, or digital whiteboards
- ELABORATE
  - Ruler
  - Phone for recording video
  - Timer
  - Transparent plastic cups (2 per group)
  - Materials that students can use to modify their slime recipes (ex. Tissue paper, more glue, other types of glue, cornstarch)
- EVALUATE: Pads of sticky notes in 2 different colors

STANDARDS

Next Generation Science Standards

- CC: Stability and Change. Change is measured in terms of differences over time and may occur at different rates.
- DCI: ETS1.A: Defining and Delimiting Engineering Problems. Possible solutions to a problem are limited by available materials and resources (constraints). The success of a designed solution is determined by considering the desired features of a solution (criteria). Different proposals for solutions can be compared on the basis of how well each one meets the specified criteria for success or how well each takes the constraints into account.
- DCI: PS1.B: Chemical Reactions. When two or more different substances are mixed, a new substance with different properties may be formed.
- SEP: Constructing Explanations and Designing Solutions. Generate and compare multiple solutions to a problem based on how well they meet the criteria and constraints of the design problem.
- SEP: Planning and Carrying Out Investigations. Make observations and measurements to produce data to serve as the basis for evidence for an explanation of a phenomenon.

Mathematics Standards | Common Core State Standards

- 8.F.A.1: Understand that a function is a rule that assigns to each input exactly one output. The graph of a function is the set of ordered pairs consisting of an input and the corresponding output.
- HSF-IF.A.1: Understand that a function from one set (called the domain) to another set (called the range) assigns to each element of the domain exactly one element of the range. If f is a function and x is an element of its domain, then f(x) denotes the output of f corresponding to the input x. The graph of f is the graph of the equation y = f(x).

English Language Arts Standards | Common Core State

- CCSS.ELA-LITERACY.RST.3: Follow precisely a complex multistep procedure when carrying out experiments, taking measurements, or performing technical tasks, attending to special cases or exceptions defined in the text.
- CCSS.ELA-LITERACY.RST.7: Translate quantitative or technical information expressed in words in a text into visual form (e.g., a table or chart) and translate information expressed visually or mathematically (e.g., in an equation) into words.
- CCSS.ELA-LITERACY.WHST.4: Produce clear and coherent writing in which the development, organization, and style are appropriate to task, purpose, and audience.
- CCSS.ELA-LITERACY.WHST.7: Conduct short as well as more sustained research projects to answer a question (including a self-generated question) or solve a problem; narrow or broaden the inquiry when appropriate; synthesize multiple sources on the subject, demonstrating understanding of the subject under investigation.
- CCSS.ELA-LITERACY.SL.4: Present information, findings, and supporting evidence clearly, concisely, and logically such that listeners can follow the line of reasoning and the organization, development, substance, and style are appropriate to purpose, audience, and task.

LESSON OBJECTIVES

Students will be able to

1. Design a material (slime) that meets certain criteria and constraints going through the engineering process
2. Test their material and collect data
3. Establish CER (claim, evidence, and reasoning) using a graphic organizer
4. Showcase and annotate projects

CAREER CONNECTIONS

Mentor Background: Dr. Travis Thornell

Dr. Thornell is a research physical scientist at the US Army Engineer Research and Development Center (ERDC) in Vicksburg, MS. He received his BS in Polymer Science from the University of Southern Mississippi (USM) in 2013 and his PhD in Materials Engineering from Purdue University in 2018. Dr. Thornell joined ERDC as a researcher in 2018 in the Concrete and Materials Branch of the Geotechnical and Structures Laboratory where he plans and conducts research in Military Engineering with internal and external partners. Recently, Dr. Thornell was selected for the 2021 American Chemical Society Partners for Progress and Prosperity (P3) award for collaborations with USM on research and academic efforts.

STEM Careers:

- CAD technician
- Design engineer
- Materials engineer
- Metallurgist
- Product/process development scientist
- Research scientist (physical sciences)
- Technical sales engineer
- R & D (research and development)
- Analytical chemist
- Biomedical engineer
- Geotechnical engineer
- Higher education lecturer
- Management consultant
- Manufacturing systems engineer
- Patent examiner
- Project manager
- Quality manager

ENGAGEMENT

Brief Description: Students examine examples of everyday products made of hydrogel or aerogel. Students communicate what structural properties these products have in common.

Procedures:

1. In small groups or gallery walk, students examine everyday items: contact lens (in transparent container), baby diaper, hair gel, aerogel shoe inserts.
2. Have students record on actual or digital whiteboards: what do these items have in common?
3. Guide students into and through discussion of material properties of gels.
4. Show short video of an example of industry application or research (example: https://youtu.be/mrcNc5UT0BM)

Scenario: You and your team are lab interns competing for a coveted research spot in a research facility to perform polymer research for the summer.

EXPLORATION

Brief Description: Students work in small groups. Each group produces one of three types of slime. Instructor guides student discussion to design tests to compare properties of each type of slime, given a set of available equipment and materials.

Procedures:
Give all groups gloves, safety glasses, and measuring instruments

Slime #1 (Borax-based)

240 ml water + 8.53g borax

1 5-ounce bottle of Elmer's School Glue (clear or white) + 120ml water

Food coloring

2 bowls

Mixing utensils

Mix water and borax together in one bowl. Then mix the glue and water together in another bowl. Add food coloring to either bowl.

After this, mix the contents of the two bowls together. It will begin to form slime. Knead it on the table after it reaches a critical mass.

Slime #2 (Sand-based)

1 5-ounce bottle of Elmer's School Glue (clear or white)

6g baking soda

45g colored sand

15ml contact lens multipurpose solution

Bowl

Mixing utensils

Empty the entire bottle of Elmer's School Glue into a bowl.

Add baking soda. Stir until the baking soda is completely mixed in with the glue.

Add colored sand. Stir the mixture again until the sand is evenly distributed.

Add contact solution. The slime will develop into a ball.

Pick the slime up and if it is too sticky, add another 7.5ml contact solution.

Slime #3 (Liquid starch-based)

1 5-ounce bottle of Elmer's School Glue (clear or white) + 150ml water

Food coloring

60ml liquid starch

Bowl

Mixing utensils

In a bowl, combine water and glue and mix well.

Add food coloring and mix well.

Pour in liquid starch and stir well.

Slime will immediately start to form and pull away from the sides of the bowl. Keep stirring until slime is completely formed and no liquid remains.

Put a few drops of liquid starch on your gloves and knead the slime. It will appear stringy at first but just work it around with your hands and you will notice the consistency change.

You can add liquid starch 5mL at a time to make the slime stiffer.

Lab Report LInk (also includes the CER at the end): Polymer Science Lab Report

EXPLANATION

Brief Description: Students apply the science of crosslinked polymers to explain the formulation and structural properties of their slime.

Procedures:
Instructor guides students to consider the chemistry of slime formation. Within their small groups, students discuss and diagram their ideas on digital boards or whiteboards. Reveal actual chemistry after students have shared their diagrams. Show diagrams of crosslinked polymers:

https://alltogether.swe.org/wp-content/uploads/2022/08/sep-engineering-activity-1.png

https://cen.acs.org/physical-chemistry/chemical-bonding/Errors-CEN-graphic-reveal-widespread/96/i28

From ACS: "The glue has long flexible molecules in it called polymers. These polymer molecules slide past each other as a liquid. Borax in water forms an ion called the borate ion. When the borax solution is added to the glue solution, the borate ions help link the long polymer molecules to each other so they cannot move and flow as easily. When enough polymer molecules get hooked together in the right way, the glue solution changes from being very liquidy to a rubbery kind of stuff that we call slime!"

From MelScience.com: "PVA glue contains long molecules of polyvinyl alcohol, while contact lens solution contains a small quantity of boric acid. Under the influence of the baking soda, the boric acid binds the polyvinyl alcohol molecules together with weak chemical bonds. As a result, the mixture thickens and turns into slime!"

ELABORATION

Brief Description: Within their groups, students decide how to modify their slime recipe in order to produce a slime that improves in some way on the original formulation. (examples: more or less viscous, supports more mass, is more elastic) Students produce slime using their modified recipe and test the new slime's properties. Students analyze whether they successfully modified their slime.

Procedures:

Elasticity:

Students will form a ball of slime and drop it on a flat surface. They will measure how well it bounces.

The measurement is taken by taking a video of the bounce that includes a ruler scale in the video.

All samples should be of uniform mass. (Do multiple samples of each of the two types of slime, original and modified recipe)

All samples should be dropped from the same height.

Measure the height that each ball bounces upward after hitting the ground.

Graph: Height of bounce vs. slime sample ID

Stretch speed:

Students will form their sample into a cylinder and record how much the slime stretches in 5 second intervals.

All cylinders of the slime samples should be of uniform size

Students hold the slime at one end, and place the other end at the top of the measuring tape marked zero.

Students record the distance the slime stretches in 5 second intervals until it either reaches the floor or snaps.

Graph: Distance stretched vs. time (each line represents a different sample ID)

Viscosity:

Students will put equal volumes of slime into two transparent cups. They will rest a ball bearing on the surface of the slime and time how long it takes for the ball bearing to hit the bottom of the cup.

Measure the height of each sample of slime in each cup (this measurement should be uniform for all samples)

Measure the time for the ball bearing to travel from the surface of the slime to the bottom of the cup

Graph: Time vs. slime sample ID

EVALUATION

Brief Description: As part of their lab reports, students will complete a CER sheet (Claim, Evidence, and Reasoning). Students will create group displays (on easel pads) around the classroom to showcase their projects. Students will circulate and use colored sticky notes to identify what was done well and to add suggestions for any part of the CER model.

Procedures:

Have one student per group display the CER sheet from the lab report on an easel or lab bench.

Give students blank sticky notes in two colors (for example, yellow and pink).

Have students gallery-walk the room and carefully consider each CER for each group.

Have students identify and explain elements of the work and CER that are well-done on yellow sticky notes and affix them near the CER.

Have students describe suggestions for further exploration or elaboration on pink sticky notes and affix them near the CER.

REFERENCES

Slime recipes were obtained and modified from the following sites:

- https://www.thoughtco.com/step-by-step-slime-instructions-604173
- https://www.smartschoolhouse.com/diy-crafts/sand-slime
- https://littlebinsforlittlehands.com/liquid-starch-slime-easy-sensory-play-recipe/
- Slime Chemistry | Science Project (sciencebuddies.org)
- C1.pdf (acs.org)
    - Rohrig, B. (2004). The science of slime!. *ChemMatters*, *22*(4), 13.

Testing methods to measure physical properties of slime were obtained and modified from the following sites:

- https://www.teachengineering.org/activities/view/usm-2398-slime-graphing-speed-tensile-strength
- https://scienceprojectideasforkids.com/starting-slime-project/

Chemistry of the reaction resulting in the formation of slime:

- https://www.acs.org/education/whatischemistry/adventures-in-chemistry/experiments/slime.html#:~:text=Borax%20in%20 water%20 forms%20an,move%20and%20 flow%20as%20 easily.
- https://melscience.com/AU-en/articles/thermochromic-slime/#:~:text=PVA%20glue%20contains%20long%20molecules,thickens%20and%20turns%20into%20slime!

Safety considerations in experiments involving boric acid and borax:

- https://missouripoisoncenter.org/homemade-slime-safe-toxic/

Possible careers associated with polymer science:

- https://www.prospects.ac.uk/

Science, Math, and ELA standards:

- https://www.nextgenscience.org/
- http://www.thecorestandards.org/Math/
- http://www.thecorestandards.org/ELA-Literacy/