AC 2011-2777: EXCHANGE: OOBLECK, SLIME, AND PLAYDOUGH MATERIALS ENGINEERING FOR THE ELEMENTARY CLASSROOM

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EXCHANGE: Oobleck, Slime, and Play Dough
Materials Engineering for the Elementary Classroom

One aspect of Materials Engineering that is accessible to young children is the opportunity to vary a "recipe" and see how that affects the properties of a substance. Children enjoy playing with materials with interesting properties: oobleck (cornstarch and water), slime (glue, borax, and water), and play dough (flour, salt, and water) fascinate. Just interacting with these substances is a great way to develop scientific descriptive vocabulary, but take it a step further with an engineering design challenge. This can be approached from three angles: (1) start with a problem to be solved, perhaps from children's literature, and challenge students to adjust the process to meet the criteria for success OR (2) start with the strange properties the substance has and come up with a problem the substance solves OR (3) design quality control tests for familiar materials. This paper will discuss some of the engineering design projects students can do with oobleck, slime, and play dough.

All lessons have been tested in elementary classrooms by the author and other classroom teachers. The author is the coordinator of one school district's STEM curriculum and teacher training efforts. The district uses a central materials center to store, schedule, and refurbish the materials kits. The process used to develop, test, revise, and implement curriculum involves four major steps: (1) curriculum development and alignment to standards, (2) piloting curriculum in classrooms, (3) revisions to curriculum based on piloting feedback, and (4) training district teachers and creating multiple copies of materials kits. Curriculum development at the district level involves a mixture of adapting commercial materials and creating new materials. The district science curriculum is matched to state standards and specific science and engineering units are taught at each grade level. For example at second grade, there are three science-engineering units: (1) Insects and Designing Hand Pollinators, (2) Solids and Liquids and Oobleck, Slime, and Play dough Materials Engineering, and (3) Air and Weather and Wind Toys. When curriculum is chosen or created, a team of veteran and early-career teachers are recruited to pilot the new lessons. The STEM curriculum coordinator meets with piloting teachers to introduce the lessons and materials kits in an after-school mini-training. The piloting teachers try out the lessons in their classrooms and then a debriefing meeting is scheduled. Feedback from piloters is used to revise the curriculum and the materials kits. A second group of piloters try out the revisions before the district purchases and assembles multiple copies of the new materials kits with teacher's guides. The new kits are stored in the central materials center for distribution and restocking. Finally, all district teachers are trained to use the new curriculum with the help of piloting teachers and professional engineers and scientists as guest speakers at the inservices. The curriculum coordinator troubleshoots any issues that come up with the new curriculum or the materials during the school year.

Oobleck, Slime, and Play dough, Materials Engineering is a unit piloted in and designed for second grade. It complements the existing science unit, FOSS Solids and Liquids[1], and meets state science and engineering standards. Piloting teachers have an hour and half initial training with an hour meeting after the piloting for discussion. Additionally the district elementary STEM coordinator spends time in piloting classrooms and assists in teaching some lessons. This curriculum is used in a district with approximately twenty-five second grade classrooms. At the district-wide inservice all teachers receive four hours training in general engineering design topics (state standards, the engineering design process, defining technology and the role of engineering etc.) as well as specific training in the use of the engineering kits assigned to their grade level.

The National Science Standards by the National Research Council[2] provide a framework and focus for materials engineering at the elementary level. Lessons involving materials are first and foremost an opportunity for students to hone their observation skills as they describe the properties of the materials. Specifically, experiences with oobleck, slime, and play dough are related to the following national science content standards, "K-4 Properties of Objects and Materials" and generally with Scientific Inquiry skill development.

- Objects have many observable properties, including size, weight, shape, color, temperature, and the ability to react with other substances.
- Materials can exist in different states—solid, liquid, and gas. Some common materials, such as water, can be changed from one state to another by heating or cooling.

Working with materials offers an opportunity to go beyond traditional science content and skills by adding an engineering design challenge. This addresses the standards for "K-4 Abilities of Technological Design:"

- Identify a simple problem**.** In problem identification, children should develop the ability to explain a problem in their own words and identify a specific task and solution related to the problem.
- Propose a solution**.** Students should make proposals to build something or get something to work better; they should be able to describe and communicate their ideas. Students should recognize that designing a solution might have constraints, such as cost, materials, time, space, or safety.
- Implementing proposed solutions**.** Children should develop abilities to work individually and collaboratively and to use suitable tools, techniques, and quantitative measurements when appropriate. Students should demonstrate the ability to balance simple constraints in problem solving.
- Evaluate a product or design**.** Students should evaluate their own results or solutions to problems, as well as those of other children, by considering how well a product or design met the challenge to solve a problem. When possible, students should use measurements and include constraints and other criteria in their evaluations. They should modify designs based on the results of evaluations.
- Communicate a problem, design, and solution**.** Student abilities should include oral, written, and pictorial communication of the design process and product. The communication might be show and tell, group discussions, short written reports, or pictures, depending on the students' abilities and the design project.

Identifying the three states of matter and their properties is an important concept in elementary science. Before tackling the materials engineering design challenges, students should brainstorm properties and possible tests for determining whether a material is a liquid or solid.
These are some of the ideas students might suggest:

- Do solid things sink into it? (liquids allow sinking, solids do not)

- Will it go through a screen? (liquids usually do, only smaller particles of solids can)
- In a bottle, what happens when you shake, roll, tip, or spin it?
- Does it soak into a thick paper towel? (liquids are absorbed, solids are usually not)
- Is the top surface flat? (liquids are flat, solids can be flat or not)
- What happens when you poke it? (Liquids let in a poke, solids may not)
- What happens when you pull on one part of it (stretch it)? (liquids elongate, solids often break)
- What happens if you dump it out on a flat surface? (liquids will spread out, solids usually retain their shape)
- Can it be molded into a shape? Can it hold that shape? (liquids do not hold their shape, solids do)
- Does it bounce? (liquids plop, solids may bounce)
- Does it pour? Does it flow easily? (standard "test" for distinguishing liquid and solid)
- Does it take the shape of its container? (standard "test" for liquid-solid distinction)

In a warm-up activity, students use the tests they have designed for determining whether a material is a liquid or solid on interesting substances such as shaving cream, wet sand, Jell-O, mayonnaise, ketchup, cottage cheese, or toothpaste. Note that besides the materials, students will need small objects (penny, paper clip, toothpick, marble, piece of string, etc.), paper towels, screens, bottles, and containers for the materials. They record their observations as they test these materials and the class discusses the results.

Once students have explored the properties of a variety of materials including tests to determine whether they are solids or liquids, they are ready for an engineering design challenge. Each of the challenges described in this paper has students identifying a problem, proposing and implementing a solution, evaluating their own and others' work, and communicating about the process.

Oobleck, a mixture of cornstarch and water, is a fascinating material seeming at times to be a solid and at other times a liquid. Oobleck (and quicksand) are also characters in children's literature: *Bartholomew and the Oobleck* by Dr. Seuss[3] and *The Quicksand Book* by Tomie DePaulo.[4] Oobleck is a star on the Discovery Channel[5] and Mythbusters[6] (see websites in bibliography).

Begin by giving students an opportunity to explore the properties of oobleck and use the solid-liquid tests from the warm-up activity. Be sure to include small objects for testing with the oobleck. Make a class list of observations to be used in the engineering challenge.

> Recipe for oobleck (enough for a small bowl for several students to share)
> Mix in a bowl: ¼ cup of water + few drops food coloring (opt.) + ½ cup cornstarch
> Keep oobleck in a sealed container in refrigerator. Dispose of in the trash, not in the sink.

Now introduce the design challenge by reading *Bartholomew and the Oobleck* by Dr. Seuss and/or *The Quicksand Book* by Tomie DePaulo. Discuss which properties of oobleck (or quicksand) were relevant in the story and the role of oobleck or quicksand as a story "character." Challenge students to write a story starring oobleck. The story students write will essentially be an engineering design adventure: the characters have a problem to solve, they learn something about the materials and use that knowledge to come up with a solution, and they try out their idea, perhaps have a couple of false starts, and finally succeed, and in the end communicate their success.

For example a student's story might be about a king who surrounds his castle with a moat of oobleck and the problem is how to get across. Various characters in the story can do science experiments to study the properties of oobleck and come up with a plan to cross….some of the ideas work and some don't with dramatic results. The first crosser walks slowly and sinks into the sticky mess, the next tries to swim and sinks, and the last runs quickly and succeeds! Engineering design has a starring role as the characters solve a problem.

An additional challenge is to have students work with oobleck recipes and use the variations as a story element. What proportions of cornstarch and water create the most solid support if you know how to move on it and which "recipe" might be sticky enough to trap intruders? Can you make up a variation of the story to match your oobleck's properties?

Slime, a mixture of glue and borax solution, is popular with children. Designing a "toy" with certain properties is another way to start the engineering design challenge. In this case the problem to be solved is the need for something fun to play with, banishing boredom.

Allow students to spend time exploring the properties of slime to see what fun things can be done with it.   Make four different recipes of slime by varying the amount of water and dye them four different colors; explore the properties of each slime recipe. Be sure to include small objects for testing with the slimes. Refer to the solid-liquid tests used in the warm-up activity.

Recipes for four versions of slime (enough for a few students to share):
A general description for making slime is available on About.com website.[7]
Mix up a saturated solution of 20 Mule Team Borax and water:
¼ cup Borax + 1 cup warm water. Shake well before using.

Red (least wet) = ¼ cup glue + 3 drops red + 2 Tbsp. water + 1 teas. Borax solution
Yellow (a little wet) = ¼ cup glue + 3 drops yellow + 5 Tbsp. water + 1 teas. Borax
Green (wet) = ¼ cup glue + 3 drops green + 8 Tbsp. water + 1 teas. Borax
Blue (very wet) = ¼ cup glue + 3 drops blue + 11 Tbsp. water + 1 teas. Borax
Dispose of slime in the trash, not down the drain.

Introduce the slime design challenge by showing a web video ad with children talking about fun materials (see web link in bibliography)[8] and/or discuss what makes an effective ad. Students choose one type of slime and design a toy or a practical use for that slime. They choose a name for their product and write an ad, produce a TV commercial, or create a poster.

If you would like to give students an additional design challenge, have them work with adjusting the slime recipe to see the effect on its properties. It is best to have students begin with a standard amount of glue (2 Tbsp. is good) and have them add varying amounts of water. The borax solution needs to be added last in small amounts, one teaspoon at a time works well.

Instruct students to stir well after each addition of borax and notice what happens to the material; it should begin to solidify and at that point no more borax solution is needed.

Starting with criteria for success is another way to launch a materials engineering design challenge. The problem to solve is having a way to determine if a material is fun to play with. Play dough is a familiar childhood material. Can students design tests to check the quality of the play dough they mix? Can they find different ways play dough can be used depending on the recipe?

Introduce the play dough challenge by reading children's literature. *Goldilocks and the Three Bears*[9 10] describes the concept of "just right" in a child-friendly way. Discuss what tests Goldilocks used to decide whether the chairs, beds, and porridge were "just right." A fun alternative is *Somebody and the Three Blairs* by Marilyn Tolhurst[11]; same idea but it's the bear that does the quality control testing.

Make two versions of play dough; one high-quality and one low-quality (see recipes below). Start by having students describe the qualities of the two materials focusing on texture. Challenge students to use the two play doughs in different ways and make a list of things they can do with the dough. Remind them of their previous experiences in the warm-up activity with creating solid-liquids tests.

Using the observations and the lists of "uses," students propose quality control tests. Typical ideas might include being able to make a snowman, make a snake, or use with cookie cutters. In discussing these tests have students clarify how they know if it makes a snake (maybe because you can use the flat of your hand rolling back and forth over a small piece of play dough and it becomes snake-shaped) or it works with cookie-cutters (you can roll it out flat and make a clean cut with cookie cutters without the dough sticking to the rolling pin). For young students, a play dough scoring guide with three scores is best; students should describe what can be done with the play dough for the best score of "3," and what constitutes the worst score of "1" and let the score of "2" be in between. This is a great opportunity for students to be involved in creating a rubric and may give them better insight into the scores they get on their work when their teacher uses a rubric for assessment.

Mix up a third batch of play dough, in between good and bad, and have students use their tests to evaluate it with their scoring rubrics.

> Play dough recipes (three versions):
> Mix these recipes in the order the ingredients are listed. Dye recipes different colors.
> Bad play dough = 2 cups flour, 1 ½ cups warm water, 1 cup salt, mix, knead
> Good play dough = use commercial play dough OR
> ¼ cup salt + ½ cup warm water, mix + 1 cup 2 Tbsp. flour, mix, knead
> So-so play dough = ¼ cup salt + ½ cup warm water, mix + 1 ¼ cup flour, knead

These engineering design activities can also be used by teachers as work samples for writing or for speech. Teachers can use their state scoring guides in writing to assess students' narrative writing in the oobleck-based story, persuasive writing in the slime ads, or expository writing in the engineering play dough report. If students do a presentation, an ad for the slime or an engineer's report for the play dough, teachers can use standard speech scoring guides to assess.

To really delve into an engineering design project with play dough, take a look at the Boston Museum of Science's Engineering is Elementary unit, *A Work in Process: Improving a Play Dough Process*.[12] This set of lessons takes students through the entire engineering design process as they explore properties of the play dough ingredients, design a process, test it, redesign, and evaluate the final product with a scoring guide. The author would like to acknowledge inspiration from EIE and from *Slime, and Dancing Spaghetti* by Jennifer Williams.[13]

This poster session will provide an opportunity to experiment with oobleck, four versions of slime, and three versions of play dough and allow participants to deduce their recipes. Examples of student work will be on display: stories starring oobleck, ads for slime toys, and testing recommendations for play dough. Fun for materials engineers of all ages!

Bibliography

1 FOSS, Full Option Science System, *Solids and Liquids,* 2001
2. National Research Council*, National Science Standards,* National Academy Press, 1996
3. Geisel, Theodore (Dr. Seuss), *Bartholomew and the Oobleck*, Random House Books for Young Readers, 1949
4. de Paola, Tomie, *The Quicksand Book,* Holiday House, 1977
5. Oobleck on Discovery channel: http://www.youtube.com/watch?v=S5SGiwS5L6I
6. Oobleck on Mythbusters: http://www.youtube.com/watch?v=-wiYtoG9kZE
7. How to make slime: http://video.about.com/chemistry/How-to-Make-Slime.htm
8. Example of an ad: http://www.youtube.com/watch?v=k2JIFQ4PiH0
9. Brett, Jan, *Goldilocks and the Three Bears,* Putnam Juvenile, 1996
10. Galdone, Paul, *The Three Bears,* Sandpiper, 1985
11. Tolhurst, Marilyn, *Somebody and the Three Blairs,* Scholastic, 1984
12. Engineering is Elementary, Museum of Science, Boston, Massachusetts, *A Work in Process: Improving a Play Dough Process, Solids and Liquids and Chemical Engineering for Elementary Students,* 2010
13. Williams, Jennifer, *Oobleck, Slime, and Dancing Spaghetti,* Bright Sky Press, 2009