

Summary of PCSA Science Kits and their inclusion of the Next Generation Science Standards (NGSS)

The framework of the NGSS is three-dimensional and includes core ideas (physical sciences, engineering technology, etc.), crosscutting concepts, and practices.

- This document breaks down each lesson of the PCSA teacher demo and student lab kits in terms of the NGSS standards and provides a short description of how each applicable standard could be applied to the lesson.
- Also included is a list of crosscutting concepts and science and engineering practices; since these are generally considered applicable for all of the lessons, they are not repeated in each lesson subsection.
- The focus audience of these kits is middle school (7th – 8th grades) and high school (9th -12th grades) students. Therefore, only standards at these grade levels will be discussed.

Crosscutting concepts

- Patterns
- Cause and effect / mechanism and explanation
- Scale, proportion, and quantity
- Systems and system models
- Energy and matter flows, cycles, and conservation
- Structure and function
- Stability and change

Science and Engineering Practices

- Asking questions and defining problems
- Developing and using models
- Planning and carrying out investigations
- Analyzing and interpreting data
- Using mathematics and computational thinking
- Constructing explanations and designing solutions
- Engaging in argument from evidence
- Obtaining, evaluating, and communicating information

Student Lab Kit

1. Chocolate Strength
 - a. MS-PS2-4 Construct and present arguments using evidence to support the claim that gravitational interactions are attractive and depend on the masses of interacting objects.
 - i. The portion of the lesson where weights are added to the chocolate to make them break can be discussed in terms of gravitational

interactions, if desired.

- b. PS1.A: Structure and Properties of Matter
 - i. The basic concept of this experiment is to analyze how the structure of the chocolate affects the strength of each bar.
2. Engineered Concrete
 - a. MS-PS1-2 Analyzing and interpreting data on properties of substances before and after the substances interact to determine if a chemical reaction occurs.
 - i. Hydration of the cement (i.e. adding the water to the cement powder and allowing it to cure) can be discussed in terms of what type of reactions occurs.
 - b. HS-PS1-5 Apply scientific principles and evidence to provide an explanation about the effects of changing the temperature or concentration of the reacting particles on the rate at which a reaction occurs.
 - i. This lesson asks students to change the amount of components in the cement composites and test their strength; this can be expanded to observe the time it takes for the hydration to occur with different amounts of components.
 - c. ETS1.B and .C Develop possible solutions and optimizing the design solution
 - i. This project walks students through experimental design, testing, revisiting the data, and refining solutions.
 - d. MS-ETS1-1 to 4 Engineering design criteria for middle school curriculum
 - i. This lesson allows for the discussion of engineering design of the cement composites. Specifically, focus can be placed on what properties are desired, and how changing the components of the system may control those properties.
3. Glass Bead on Wire
 - a. PS1.A: Structure and Properties of Matter
 - i. This lesson explains the various structures of matter.
 - b. MS-PS1-4 Develop model that predicts and describes changes in particle motion, temperature, and state of pure substance when thermal energy is added or removed.
 - i. This experiment can be thought of as a model that explains the various structures or states of glass, crystalline, and semi crystalline materials, and how temperature has an effect on the corresponding structure.
 - c. MS-PS1-2 Analyzing and interpreting data on properties of substances before and after the substances interact to determine if a chemical reaction occurs.
 - i. The background information section explains what is happening when borax and metal wires are heated – the class can determine if this is a chemical reaction.

- d. HS-PS1-5 Apply scientific principles and evidence to provide an explanation about the effects of changing the temperature or concentration of the reacting particles on the rate at which a reaction occurs.
 - i. Both temperature and the type of wire being used can be varied to see the effect each has on the resulting bead formation.
 - e. HS-PS1-8 Plan and conduct an investigation to gather evidence to compare the structure of substances at the bulk scale to infer the strength of electrical forces between particles.
 - i. The effect of adding heat to change the structure of the borax can be further expanded upon to discuss the forces between particles.
4. Happy Ball/Sad Ball
- a. MS-PS1-4 Develop a model that predicts and describes changes in particle motion, temperature, and state of pure substance when thermal energy is added or removed.
 - i. This lesson demonstrates the temperature dependence of material structure and properties.
 - b. MS-PS3-4 Plan an investigation to determine the relationships among the energy transferred, the type of matter, the mass, and the change in the average kinetic energy of the particles as measured by the temperature of the sample.
 - i. This can be seen by relating the height of the balls bouncing at various temperatures to the internal molecular structure of the different balls materials.
 - c. PS1.A Structure and Properties of Matter
 - i. Generally, the entire concept of this experiment is how the structure of the two balls affects their properties.
 - d. MS-PS2-1 Apply Newton's Third Law to design a solution to a problem involving the motion of two colliding objects.
 - i. It is possible to expand the discussion to discuss the physics between colliding objects and why things bounce.
 - e. MS-PS3-1 Construct and interpret graphical displays of data to describe the relationships of kinetic energy to the mass of an object and the speed of an object.
 - i. It is possible to discuss the kinetic energy and potential energy of the bouncing balls.
 - f. HS-PS2-6 Communicate scientific and technical information about why the molecular-level structure is important in the functioning of designed materials.
 - i. The main idea of this experiment is to show why the molecular-level structure affects the functionality of the materials.

- g. HS-PS1-8 Plan and conduct an investigation to gather evidence to compare the structure of substances at the bulk scale to infer the strength of electrical forces between particles.
 - i. This can be discussed in relation to the density and properties of the different balls.
 - h. HS-PS2-3 Apply scientific and engineering ideas to design, evaluate, and refine a device that minimizes the force on a macroscopic object during a collision.
 - i. The students could discuss what criteria are needed to design a ball that bounces at low temperatures etc.
5. Thermal Processing of Bobby Pins
- a. MS-PS1-4 Develop a model that predicts and describes changes in particle motion, temperature, and state of pure substance when thermal energy is added or removed.
 - i. The thermal processing induces solid phase transformations in the bobby pins.
 - b. PS1.A: Structure and Properties of Matter
 - i. The main concept of this experiment is determining how a change in the phase or atomic structure of the bobby pin has an effect on the properties of the pin.
 - c. MS-PS1-2 Analyzing and interpreting data on properties of substances before and after the substances interact to determine if a chemical reaction occurs.
 - i. Discuss how to distinguish a solid phase change from a chemical reaction.
 - d. HS-PS2-6 Communicate scientific and technical information about why the molecular-level structure is important in the functioning of designed materials.
 - i. The main concept of this experiment is determining how a change in the phase or atomic structure of the bobby pin has an effect on the properties of the pin.
 - e. MS-PS1-1 Develop models to describe atomic composition of simple molecules and extended structures.
 - i. Images could be shown of the atomic structure of the different phases of the pin (i.e. annealed steel vs. quenched steel vs. plain steel).
 - f. MS-PS2-4 Construct and present arguments using evidence to support the claim that gravitational interactions are attractive and depend on the masses of interacting objects.
 - i. In this lab the force, moment of inertia, and deflection of the pins are calculated.

Teacher Demo Kit

1. Candy Fiber Pull

- a. MS-PS1-4 Develop a model that predicts and describes changes in particle motion, temperature, and state of a pure substance when thermal energy is added or removed.
 - i. The experiment itself can be a model showing what happens when the structure of a material changes with changing temperature.
- b. MS-PS3-4 Plan an investigation to determine the relationships among the energy transferred, the type of matter, the mass, and the change in the average kinetic energy of the particles as measured by the temperature of the sample.
 - i. Discuss how the structure of the candy changes to a more liquid-like state when hot (atoms more mobile due to higher energy input) and then becomes glass-like (brittle) when cooled quickly.

2. Hot or Not

- a. MS-PS3-3 Apply scientific principles to design, construct, and test a device that either minimizes or maximizes thermal energy transfer.
 - i. This lesson minimizes thermal energy transfer and explains how the structure of the refractory brick decreases thermal conductivity.
- b. MS-PS3-4 Plan an investigation to determine the relationships among the energy transferred, the type of matter, the mass, and the change in the average kinetic energy of the particles as measured by the temperature of the sample.
 - i. This lesson explains how heat is transferred through a solid material and explains why refractories reduce heat transfer. It can easily be expanded to explain why non-refractory metals are good at conducting heat.

3. Making Plastic

- a. MS-PS1-1 Develop models to describe the atomic composition of simple molecules and extended structures.
 - i. The introduction explains the structure of a polymer, and how it is made up of many subunits.
- b. MS-PS1-3 Gather and make sense of information to describe that synthetic materials come from natural resources and impact society.
 - i. This lesson involves making plastic (synthetic) out of milk and vinegar (somewhat natural) – it goes into more detail about this in the discussion questions.
- c. MS-PS1-2 Analyze and interpret data on the properties of substances before and after the substances interact to determine if a chemical reaction has occurred.
 - i. A chemical reaction occurs between the reactants (milk and vinegar)

to form a new substance with different properties.

- d. HS-PS1-4 Develop a model to illustrate that the release or absorption of energy from a chemical reaction system depends upon the changes in total bond energy.
 - i. A discussion could be included on how adding heat to the system causes a chemical reaction to occur.
 - ii. A qualitative discussion regarding the difference in bond strength of the liquid vinegar and milk to the bond strength of the polymer can also be included.
- 4. Piezoelectric Materials
 - a. MS-PS2-3 Ask questions about data to determine the factors that affect the strength of electric and magnetic forces.
 - i. The piezoelectric response is caused by applying a physical force to the material that results in the output of an electric charge. This lesson could be modified to test the correlation between force and charge output.
- 5. Shape Memory Alloys
 - a. MS-PS1-1 Develop models to describe the atomic composition of simple molecules and extended structures.
 - i. This lesson discusses the unit cell of two different phases of Nitinol which, when repeated, creates the bulk structure.
 - b. PS1.A: Structure and Properties of Matter
 - i. This lesson also explains how the change in crystallographic structure causes the shape-memory properties.
 - c. HS-PS2-6 Communicate scientific and technical information about why the molecular-level structure is important in the functioning of designed materials.
 - i. This lesson shows that the arrangement of atoms - which defines the phase of the material - corresponds to different material properties